MARKS & CLERK
Patent and Trade Mark Attorneys

European Patent Attorneys
Chartered Patent Attorneys
European Trade Mark Attorneys
Registered Trade Mark Attorneys

Birmingham Office
Alpha Tower
Suffolk Street Queensway
Birmingham B1 1TT

Tel: +44 (0)121 643 5881
Fax: +44 (0)121 606 4766
+44 (0)121 634 2342
birmingham@marks-clerk.com
www.marks-clerk.com

CONFIRMATION

European Patent Office
Directorate General 2
Erhardtstrasse 27
D -80298
München
Germany

Our Ref: F074196PEP

EPO - Munich
20
02. Mai 2007

27 April 2007

Dear Sirs

European Patent Application No. 04744392.4
In the name of Koninklijke Philips Electronics N.V.
For 'Method Of Measuring Sub-Micron Trench Structures'

We respond to the Official Communication pursuant to Article 96(2) EPC dated 28 November 2006. Please find enclosed a set of amended claims on pages numbered 12 and 13 as a replacement for all of the claims of the application on file. In addition, we enclose copies of a replacement for page 3 where the description has been amended to ensure consistency with the claims.

The claims have been amended in the manner indicated on the attached marked-up copy. Specifically, claim 1 has been amended to define a method for measuring an *unfilled* pattern structure, support for which may be found at page 3, lines 1 to 6 as well as in Figures 2a and 2b. The amendment which states 'the pattern comprising features each having a width dimension' is supported by the description at page 3, lines 11 to 12, as well as at page 6, line 21 and in other places throughout the description. The step of 'exciting' has been amended to define 'irradiating the unfilled patterned structure...', support for which can be found at page 3, line 17. This clause of the claims has also been amended to state 'wherein the surface acoustic waves have a wavelength larger than the feature width dimensions'. Support for this amendment can be found at page 7, lines 3 to 4. Finally, the determining step has been amended to recite 'determining a surface acoustic wave phase velocity from the signal wave form and...' support for this amendment can be found at page 6, lines 17 to 19.

Claim 2 is a new claim, dependent on claim 1 and stating that the unfilled patterned structure comprises a plurality of unfilled trenches. Support for this can be found in various places in the description, for example at page 7, lines 1 to 3 and in Figure 2.

The subsequent claims have been renumbered, but are otherwise unamended, save that claims 16 and 17 no longer define 'analysis of the signal wave form', as this expression is redundant due to the amendments of claim 1.

We submit that the claims comply with Article 123 (2) EPC and that no new subject matter has been added.

Regarding the prior art documents D1 to D6, claim 1 has been amended to recite that 'the surface acoustic waves have a wavelength larger than the feature width dimensions'. The prior art discusses measurement techniques in which the feature width dimension of the measured structure is larger than the measurement spot size. With the present invention, the measured structure has a feature width dimension smaller than the surface acoustic wavelength, i.e., smaller than the measurement spot size. In addition, the prior art discusses structures that are filled to form a continuous film rather than remaining as a raised pattern.

According to D1 and D2, a trench profile is measured by scanning the ISTS spot across the trench, as correctly noted by the Examiner. Thus, the trench width must be larger than the ISTS spot size, and consequently, much larger than the wavelength of the surface acoustic waves, because in ISTS the spot size is always larger than the acoustic wavelength. The method described in D1 and D2 is no applicable to the measurement of submicron trenches used in the current state-of-the-art microelectronics. Note, for example, that the trench width in D2, Figure 3 is 250μm.

With the present invention, the trench width must be smaller than the acoustic wavelength, and consequently much smaller than the spot size. The measurement spot covers many trenches. Thus, the method is capable of measuring submicron trenches. A further advantage of the present invention is that the method may be used to measure trenches fabricated in a bulk material (e.g. in a silicon substrate), while the prior art method described in D1 and D2 is only applicable to trenches fabricated in thin film.

References D3 to D6 describe measurements of arrays of metal lines embedded in a dielectric film (also referred to as damascene arrays). Damascene arrays are fabricated by forming trenches in a dielectric thin film, filling the trenches with metal and removing the excess metal from the surface by a polishing process. Thus, the line arrays described in D3 to D6 are typically characterised by a smooth, polished surface. The measurement principle in D3 to D6 is similar to conventional ISTS measurements of thin films in that it is based on the dependence of the surface acoustic wave velocity on the thickness of a thin film structure. Note that even if the damascene array has a surface topography (e.g. due to a non-perfect polishing process), the method described in D3 to D6 does not measure this topography, but rather the thickness of the array.

In the method of the present invention, the measurement is based on an entirely different physical phenomenon - i.e. the dependence of the surface acoustic wave velocity on the surface profile rather than on the film thickness. Consequently, the inventive method can be applied to the measurement of unfilled trench structures. In addition, the unfilled trenches may be fabricated in a silicon substrate with no thin films present.

In light of the above, we submit that the invention defined in claim 1 is both novel and contains an inventive step.

In light of the above it is believed that the objections raised have been overcome and that the application should now be in a suitable condition for grant. Should the Examiner wish to raise any

further matters we request that these be dealt with in writing or by telephone. Should the Examiner be minded to refuse the application, we request that this is not done until we are first given an opportunity for Oral Proceedings.

Yours faithfully

T. R. Somervell

Thomas R. Somervell
European Patent Attorney
MARKS & CLERK
E-mail: tsomervell@marks-clerk.com

Marked-Up Amendments to claims

1. A method for measuring an unfilled patterned structure, the pattern comprising features each having a width dimension, the method comprising:

irradiating the unfilled patterned ~~exciting the~~ structure with a spatially periodic laser intensity pattern in order to excite ~~generate~~ surface acoustic waves, wherein the surface acoustic waves have a wavelength larger than the feature width dimensions;

diffracting a probe laser beam off the generated surface acoustic waves to form a signal beam;

detecting the signal beam as a function of time to generate a signal waveform; and

determining a surface acoustic wave phase velocity from the signal waveform~~;~~ and

~~determining~~ at least one property of the patterned structure based on the effect of the surface profile on the surface acoustic wave phase velocity.

2. The method of Claim 1, wherein the unfilled patterned structure comprises a plurality of unfilled trenches.

3 ~~2~~. The method of Claim 1, wherein the exciting step further comprises a spatially periodic laser intensity pattern having a period ranging from 1 to 20 microns.

4 ~~3~~. The method of Claim 2 ~~1~~, wherein the unfilled patterned structure comprises trenches equal to or less than approximately 2 μm in width.

5 ~~4~~. The method of Claim 4 ~~3~~, wherein the unfilled patterned structure further comprises a periodic array of trenches.

6 ~~5~~. The method of Claim 5 ~~4~~, wherein the unfilled patterned structure further comprises a periodic array of linear trenches.

7 ~~6~~. The method of Claim 5 ~~4~~, wherein the unfilled patterned structure further comprises a two-dimensional periodic array of trenches.

8 ~~7~~. The method of Claim 5 ~~4~~, wherein the trenches are fabricated in a silicon substrate.

9 ~~8~~. The method of Claim 4 ~~3~~, wherein the trenches are fabricated in a thin film.

10 ~~9~~. The method of Claim 2 ~~1~~, wherein the at least one property comprises trench depth.

11 ~~10~~. The method of Claim 2 ~~1~~, wherein the at least one property comprises trench width.

12 ~~11~~. The method of Claim 1, wherein the at least one property comprises a depth profile of the unfilled patterned ~~trench~~ structure.

13 ~~12~~. The method of Claim 1, wherein the determining step further comprises combining measurements at multiple acoustic wavelengths to determine multiple parameters of the unfilled patterned ~~trench~~ structure.

14 ~~13~~. The method of Claim 6 ~~5~~, wherein the determining step further comprises combining measurements along and across the trench structure to determine both trench depth and width.

15 ~~14~~. The method of Claim 1, wherein the determining step further comprises combining measurements within and outside the unfilled patterned ~~trench~~ area to separate the effect on the surface acoustic wave velocity caused by the surface profile from other effects such as film thickness.

16 ~~15~~. The method of Claim 1, wherein the determining step ~~comprises analysis of the signal waveform with~~ employs a theoretical model based on effective elastic properties of the structure.

17 ~~16~~. The method of Claim 1, wherein the determining step ~~comprises analysis of the signal waveform with~~ employs a model based on an empirical calibration.

patent 6,256, 100, the method described above is applied to measure the effective thickness of composite structures formed of narrow (i. e. micron or submicron width) trenches etched in dielectric material and filled with metal. However, this method had not been applied to measuring trench structures prior to metal filling.

In addition, no studies have been done for high-aspect- ratio sub-micron structures which are of the most interest for practical applications.

Accordingly, it would be desirable to provide a method that can measure trench structures on the order of 0.1 μm in width.

According to the present invention there is provided a method for measuring an unfilled patterned structure as defined in claim 1 below.

The present invention meets the need for a method that can measure trench structures on the order of 0.1 um at least in one aspect. In one aspect, a method measures a patterned structure. One step of the method is exciting the structure by irradiating it with a spatially periodic laser intensity pattern in order to generate surface acoustic waves. Other steps are diffracting a probe laser beam off a thermal grating to form a signal beam; detecting the signal beam as a function of time to generate a signal waveform; and determining at least one property of the patterned structure based on the effect of the surface profile on surface acoustic wave phase velocity.

Claims

1. A method for measuring an unfilled patterned structure, the pattern comprising features each having a width dimension, the method comprising:

irradiating the unfilled patterned structure with a spatially periodic laser intensity pattern in order to excite surface acoustic waves, wherein the surface acoustic waves have a wavelength larger than the feature width dimensions;

diffracting a probe laser beam off the generated surface acoustic waves to form a signal beam;

detecting the signal beam as a function of time to generate a signal waveform; and

determining a surface acoustic wave phase velocity from the signal waveform and at least one property of the patterned structure based on the effect of the surface profile on the surface acoustic wave phase velocity.

2. The method of Claim 1, wherein the unfilled patterned structure comprises a plurality of unfilled trenches.

3. The method of Claim 1, wherein the exciting step further comprises a spatially periodic laser intensity pattern having a period ranging from 1 to 20 microns.

4. The method of Claim 2, wherein the unfilled patterned structure comprises trenches equal to or less than approximately 2 μm in width.

5. The method of Claim 4, wherein the unfilled patterned structure further comprises a periodic array of trenches.

6. The method of Claim 5, wherein the unfilled patterned structure further comprises a periodic array of linear trenches.

7. The method of Claim 5, wherein the unfilled patterned structure further comprises a two-dimensional periodic array of trenches.

8. The method of Claim 5, wherein the trenches are fabricated in a silicon

substrate.

9. The method of Claim 4, wherein the trenches are fabricated in a thin film.

10. The method of Claim 2, wherein the at least one property comprises trench depth.

11. The method of Claim 2, wherein the at least one property comprises trench width.

12. The method of Claim 1, wherein the at least one property comprises a depth profile of the unfilled patterned structure.

13. The method of Claim 1, wherein the determining step further comprises combining measurements at multiple acoustic wavelengths to determine multiple parameters of the unfilled patterned structure.

14. The method of Claim 6 wherein the determining step further comprises combining measurements along and across the trench structure to determine both trench depth and width.

15. The method of Claim 1, wherein the determining step further comprises combining measurements within and outside the unfilled patterned area to separate the effect on the surface acoustic wave velocity caused by the surface profile from other effects such as film thickness.

16. The method of Claim 1, wherein the determining step employs a theoretical model based on effective elastic properties of the structure.

17. The method of Claim 1, wherein the determining step employs a model based on an empirical calibration.

MARKS & CLERK

Patent and Trade Mark Attorneys

European Patent Attorneys
Chartered Patent Attorneys
European Trade Mark Attorneys
Registered Trade Mark Attorneys

Birmingham Office
Alpha Tower
Suffolk Street Queensway
Birmingham B1 1TT

Tel: +44 (0)121 643 5881
Fax: +44 (0)121 606 4766
+44 (0)121 634 2342
birmingham@marks-clerk.com
www.marks-clerk.com

European Patent Office
Directorate General 2
Erhardtstrasse 27
D -80298
München
Germany

Our Ref: F074196PEP

27 April 2007

Dear Sirs

European Patent Application No. 04744392.4
In the name of Koninklijke Philips Electronics N.V.
For 'Method Of Measuring Sub-Micron Trench Structures'

We respond to the Official Communication pursuant to Article 96(2) EPC dated 28 November 2006. Please find enclosed a set of amended claims on pages numbered 12 and 13 as a replacement for all of the claims of the application on file. In addition, we enclose copies of a replacement for page 3 where the description has been amended to ensure consistency with the claims.

The claims have been amended in the manner indicated on the attached marked-up copy. Specifically, claim 1 has been amended to define a method for measuring an *unfilled* pattern structure, support for which may be found at page 3, lines 1 to 6 as well as in Figures 2a and 2b. The amendment which states 'the pattern comprising features each having a width dimension' is supported by the description at page 3, lines 11 to 12, as well as at page 6, line 21 and in other places throughout the description. The step of 'exciting' has been amended to define 'irradiating the unfilled patterned structure...', support for which can be found at page 3, line 17. This clause of the claims has also been amended to state 'wherein the surface acoustic waves have a wavelength larger than the feature width dimensions'. Support for this amendment can be found at page 7, lines 3 to 4. Finally, the determining step has been amended to recite 'determining a surface acoustic wave phase velocity from the signal wave form and...' support for this amendment can be found at page 6, lines 17 to 19.

Claim 2 is a new claim, dependent on claim 1 and stating that the unfilled patterned structure comprises a plurality of unfilled trenches. Support for this can be found in various places in the description, for example at page 7, lines 1 to 3 and in Figure 2.

The subsequent claims have been renumbered, but are otherwise unamended, save that claims 16 and 17 no longer define 'analysis of the signal wave form', as this expression is redundant due to the amendments of claim 1.

We submit that the claims comply with Article 123 (2) EPC and that no new subject matter has been added.

Regarding the prior art documents D1 to D6, claim 1 has been amended to recite that 'the surface acoustic waves have a wavelength larger than the feature width dimensions'. The prior art discusses measurement techniques in which the feature width dimension of the measured structure is larger than the measurement spot size. With the present invention, the measured structure has a feature width dimension smaller than the surface acoustic wavelength, i.e., smaller than the measurement spot size. In addition, the prior art discusses structures that are filled to form a continuous film rather than remaining as a raised pattern.

According to D1 and D2, a trench profile is measured by scanning the ISTS spot across the trench, as correctly noted by the Examiner. Thus, the trench width must be larger than the ISTS spot size, and consequently, much larger than the wavelength of the surface acoustic waves, because in ISTS the spot size is always larger than the acoustic wavelength. The method described in D1 and D2 is no applicable to the measurement of submicron trenches used in the current state-of-the-art microelectronics. Note, for example, that the trench width in D2, Figure 3 is 250μm.

With the present invention, the trench width must be smaller than the acoustic wavelength, and consequently much smaller than the spot size. The measurement spot covers many trenches. Thus, the method is capable of measuring submicron trenches. A further advantage of the present invention is that the method may be used to measure trenches fabricated in a bulk material (e.g. in a silicon substrate), while the prior art method described in D1 and D2 is only applicable to trenches fabricated in thin film.

References D3 to D6 describe measurements of arrays of metal lines embedded in a dielectric film (also referred to as damascene arrays). Damascene arrays are fabricated by forming trenches in a dielectric thin film, filling the trenches with metal and removing the excess metal from the surface by a polishing process. Thus, the line arrays described in D3 to D6 are typically characterised by a smooth, polished surface. The measurement principle in D3 to D6 is similar to conventional ISTS measurements of thin films in that it is based on the dependence of the surface acoustic wave velocity on the thickness of a thin film structure. Note that even if the damascene array has a surface topography (e.g. due to a non-perfect polishing process), the method described in D3 to D6 does not measure this topography, but rather the thickness of the array.

In the method of the present invention, the measurement is based on an entirely different physical phenomenon - i.e. the dependence of the surface acoustic wave velocity on the surface profile rather than on the film thickness. Consequently, the inventive method can be applied to the measurement of unfilled trench structures. In addition, the unfilled trenches may be fabricated in a silicon substrate with no thin films present.

In light of the above, we submit that the invention defined in claim 1 is both novel and contains an inventive step.

In light of the above it is believed that the objections raised have been overcome and that the application should now be in a suitable condition for grant. Should the Examiner wish to raise any

further matters we request that these be dealt with in writing or by telephone. Should the Examiner be minded to refuse the application, we request that this is not done until we are first given an opportunity for Oral Proceedings.

Yours faithfully

T. R. Somervell

Thomas R. Somervell
European Patent Attorney
MARKS & CLERK
E-mail: tsomervell@marks-clerk.com

patent 6,256, 100, the method described above is applied to measure the effective thickness of composite structures formed of narrow (i. e. micron or submicron width) trenches etched in dielectric material and filled with metal. However, this method had not been applied to measuring trench structures prior to metal filling.

In addition, no studies have been done for high-aspect- ratio sub-micron structures which are of the most interest for practical applications.

Accordingly, it would be desirable to provide a method that can measure trench structures on the order of 0.1 µm in width.

According to the present invention there is provided a method for measuring an unfilled patterned structure as defined in claim 1 below.

The present invention meets the need for a method that can measure trench structures on the order of 0.1 um at least in one aspect. In one aspect, a method measures a patterned structure. One step of the method is exciting the structure by irradiating it with a spatially periodic laser intensity pattern in order to generate surface acoustic waves. Other steps are diffracting a probe laser beam off a thermal grating to form a signal beam; detecting the signal beam as a function of time to generate a signal waveform; and determining at least one property of the patterned structure based on the effect of the surface profile on surface acoustic wave phase velocity.

Marked-Up Amendments to claims

1. A method for measuring an unfilled patterned structure, the pattern comprising features each having a width dimension, the method comprising:

irradiating the unfilled patterned ~~exciting the~~ structure with a spatially periodic laser intensity pattern in order to excite ~~generate~~ surface acoustic waves, wherein the surface acoustic waves have a wavelength larger than the feature width dimensions;

diffracting a probe laser beam off the generated surface acoustic waves to form a signal beam;

detecting the signal beam as a function of time to generate a signal waveform; and

determining a surface acoustic wave phase velocity from the signal waveform~~;~~ and

~~determining~~ at least one property of the patterned structure based on the effect of the surface profile on the surface acoustic wave phase velocity.

2. The method of Claim 1, wherein the unfilled patterned structure comprises a plurality of unfilled trenches.

3 ~~2~~. The method of Claim 1, wherein the exciting step further comprises a spatially periodic laser intensity pattern having a period ranging from 1 to 20 microns.

4 ~~3~~. The method of Claim 2 ~~1~~, wherein the unfilled patterned structure comprises trenches equal to or less than approximately 2 μm in width.

5 ~~4~~. The method of Claim 4 ~~3~~, wherein the unfilled patterned structure further comprises a periodic array of trenches.

6 ~~5~~. The method of Claim 5 ~~4~~, wherein the unfilled patterned structure further comprises a periodic array of linear trenches.

7 ~~6~~. The method of Claim 5 ~~4~~, wherein the unfilled patterned structure further comprises a two-dimensional periodic array of trenches.

8 ~~7~~. The method of Claim 5 ~~4~~, wherein the trenches are fabricated in a silicon substrate.

9 ~~8~~. The method of Claim 4 ~~3~~, wherein the trenches are fabricated in a thin film.

10 ~~9~~. The method of Claim 2 ~~1~~, wherein the at least one property comprises trench depth.

11 ~~10~~. The method of Claim 2 ~~1~~, wherein the at least one property comprises trench width.

12 ~~11~~. The method of Claim 1, wherein the at least one property comprises a depth profile of the unfilled patterned ~~trench~~ structure.

13 ~~12~~. The method of Claim 1, wherein the determining step further comprises combining measurements at multiple acoustic wavelengths to determine multiple parameters of the unfilled patterned ~~trench~~ structure.

14 ~~13~~. The method of Claim 6 ~~5~~, wherein the determining step further comprises combining measurements along and across the trench structure to determine both trench depth and width.

15 ~~14~~. The method of Claim 1, wherein the determining step further comprises combining measurements within and outside the unfilled patterned ~~trench~~ area to separate the effect on the surface acoustic wave velocity caused by the surface profile from other effects such as film thickness.

16 ~~15~~. The method of Claim 1, wherein the determining step ~~comprises analysis of the signal waveform with~~ employs a theoretical model based on effective elastic properties of the structure.

17 ~~16~~. The method of Claim 1, wherein the determining step ~~comprises analysis of the signal waveform with~~ employs a model based on an empirical calibration.

Claims

1. A method for measuring an unfilled patterned structure, the pattern comprising features each having a width dimension, the method comprising:

irradiating the unfilled patterned structure with a spatially periodic laser intensity pattern in order to excite surface acoustic waves, wherein the surface acoustic waves have a wavelength larger than the feature width dimensions;

diffracting a probe laser beam off the generated surface acoustic waves to form a signal beam;

detecting the signal beam as a function of time to generate a signal waveform; and

determining a surface acoustic wave phase velocity from the signal waveform and at least one property of the patterned structure based on the effect of the surface profile on the surface acoustic wave phase velocity.

2. The method of Claim 1, wherein the unfilled patterned structure comprises a plurality of unfilled trenches.

3. The method of Claim 1, wherein the exciting step further comprises a spatially periodic laser intensity pattern having a period ranging from 1 to 20 microns.

4. The method of Claim 2, wherein the unfilled patterned structure comprises trenches equal to or less than approximately 2 μm in width.

5. The method of Claim 4, wherein the unfilled patterned structure further comprises a periodic array of trenches.

6. The method of Claim 5, wherein the unfilled patterned structure further comprises a periodic array of linear trenches.

7. The method of Claim 5, wherein the unfilled patterned structure further comprises a two-dimensional periodic array of trenches.

8. The method of Claim 5, wherein the trenches are fabricated in a silicon

substrate.

9. The method of Claim 4, wherein the trenches are fabricated in a thin film.

10. The method of Claim 2, wherein the at least one property comprises trench depth.

11. The method of Claim 2, wherein the at least one property comprises trench width.

12. The method of Claim 1, wherein the at least one property comprises a depth profile of the unfilled patterned structure.

13. The method of Claim 1, wherein the determining step further comprises combining measurements at multiple acoustic wavelengths to determine multiple parameters of the unfilled patterned structure.

14. The method of Claim 6 wherein the determining step further comprises combining measurements along and across the trench structure to determine both trench depth and width.

15. The method of Claim 1, wherein the determining step further comprises combining measurements within and outside the unfilled patterned area to separate the effect on the surface acoustic wave velocity caused by the surface profile from other effects such as film thickness.

16. The method of Claim 1, wherein the determining step employs a theoretical model based on effective elastic properties of the structure.

17. The method of Claim 1, wherein the determining step employs a model based on an empirical calibration.

European Patent Office
80298 MUNICH
GERMANY
Tel.: +49 89 2399 - 0
Fax: +49 89 2399 - 4465

Europäisches Patentamt | **European Patent Office** | **Office européen des brevets**

Hackett, Sean James
Marks & Clerk,
Patent Attorneys,
Alpha Tower,
Suffolk Street Queensway
Birmingham B1 1TT
GRANDE BRETAGNE

Formalities Officer

Name:XXXXXX Micu, Florentina

Tel.: XXXXX 8694

Date
11.04.07

Reference	Application No./Patent No.
F074196PEP	04744392.4 - 2204
Applicant/Proprietor	
Advanced Metrology Systems, LLC	

Extension of time limit pursuant to Rule 84 EPC

Examination procedure

With reference to your request, the time limit for replying to the communication dated 28.11.06 has been extended

by 2 months

to a total of 6 months

from the date of notification of the above-mentioned communication.

Please note: To the extent that your request exceeded the above extension, your request has been refused.

Note:
The granting of extensions to time limits is governed by the implementing Regulations to the EPC and the Guidelines for Examination in the EPO, part E-VIII, 1.6.

If no reply to the communication is received in due time, the European patent application will be deemed to be withdrawn (Article 96(3) EPC).

Examining Division

Europäisches Patentamt • European Patent Office • Office européen des brevets •

MARKS & CLERK

Patent and Trade Mark Attorneys

European Patent Attorneys
Chartered Patent Attorneys
European Trade Mark Attorneys
Registered Trade Mark Attorneys

Birmingham Office
Alpha Tower
Suffolk Street Queensway
Birmingham B1 1TT

Tel: +44 (0)121 643 5881
Fax: +44 (0)121 606 4766
+44 (0)121 634 2342
birmingham@marks-clerk.com
www.marks-clerk.com

CONFIRMATION

European Patent Office
Directorate General 2
Erhardtstrasse 27
D -80298
München
Germany

Our Ref: F074196PEP

27 March 2007

EPO - Munich
47
28. März 2007

Dear Sirs

Patent Application No. 04744392.4 in Europe
Koninklijke Philips Electronics N.V.
Method Of Measuring Sub-Micron Trench Structures

We hereby request an extension of two-months for responding to the Official Action pursuant to Article 96(2) EPC dated 28 November 2006 issued in connection with the above referenced European patent application.

Yours faithfully

T. R. Somervell

Thomas R. Somervell
European Patent Attorney
MARKS & CLERK
E-mail: tsomervell@marks-clerk.com

MARKS & CLERK

Patent and Trade Mark Attorneys

European Patent Attorneys
Chartered Patent Attorneys
European Trade Mark Attorneys
Registered Trade Mark Attorneys

Birmingham Office
Alpha Tower
Suffolk Street Queensway
Birmingham B1 1TT

Tel: +44 (0)121 643 5881
Fax: +44 (0)121 606 4766
+44 (0)121 634 2342
birmingham@marks-clerk.com
www.marks-clerk.com

European Patent Office
Directorate General 2
Erhardtstrasse 27
D -80298
München
Germany

Our Ref: F074196PEP

27 March 2007

Dear Sirs

Patent Application No. 04744392.4 in Europe
Koninklijke Philips Electronics N.V.
Method Of Measuring Sub-Micron Trench Structures

We hereby request an extension of two-months for responding to the Official Action pursuant to Article 96(2) EPC dated 28 November 2006 issued in connection with the above referenced European patent application.

Yours faithfully

T. R. Somervell

Thomas R. Somervell
European Patent Attorney
MARKS & CLERK
E-mail: tsomervell@marks-clerk.com

European Patent Office
80298 MUNICH
GERMANY
Tel.: +49 89 2399 - 0
Fax: +49 89 2399 - 4465

Europäisches Patentamt | **European Patent Office** | **Office européen des brevets**

Hackett, Sean James
Marks & Clerk,
Patent Attorneys,
Alpha Tower,
Suffolk Street Queensway
Birmingham B1 1TT
GRANDE BRETAGNE

Formalities Officer
Name: Conner
Tel.: 2241

Date	
	21.03.07

Reference	Application No./Patent No.
F074196PEP	04744392.4 - 2204
Applicant/Proprietor	
Advanced Metrology Systems, LLC	

Communication

concerning the registration of amendments relating to

☑ a transfer (Rules 20 and 61 EPC)

☐ entries pertaining to the applicant/the proprietor (Rule 92(1)(f) EPC)

As requested, the entries pertaining to the applicant of the above-mentioned European patent application / to the proprietor of the above-mentioned European patent have been amended to the following:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PL PT RO SE SI SK TR
Advanced Metrology Systems, LLC
12 Michigan Drive
Natick, MA 01760/US

The registration of the changes has taken effect on 12.03.07.

In the case of a published application/a patent, the change will be recorded in the Register of European Patents and published in the European Patent Bulletin (Section I.12/II.12).

Your attention is drawn to the fact that, in the case of the registration of a transfer, any automatic debit order only ceases to be effective from the date of its express revocation (cf. point 14(c) of the Arrangements for the automatic debiting procedure, Supplement to OJ EPO 2/2002).

Transfer Service
Tel.: +49 (0)89 2399 2780

Europäisches Patentamt • European Patent Office • Office européen des brevets

Ustelle

MARKS & CLERK

Patent and Trade Mark Attorneys

European Patent Attorneys
Chartered Patent Attorneys
European Trade Mark Attorneys
Registered Trade Mark Attorneys

Birmingham Office
Alpha Tower
Suffolk Street Queensway
Birmingham B1 1TT

Tel: +44 (0)121 643 5881
Fax: +44 (0)121 606 4766
+44 (0)121 634 2342
birmingham@marks-clerk.com
www.marks-clerk.com

The European Patent Office
Directorate General 2
D-80298 Munich
GERMANY

Our Ref: F011257PMI

8th March 2007

F.A.O. Margaret Turza

Dear Sirs

re: **European Patent Applications in the name of Koninklijke Philips Electronics N.V.**

Further to my letter dated 12 February 2007 and subsequent phone call on 6th March 2007, the address for Advanced Metrology Systems, LLC. is as follows:

12 Michigan Drive
Natick
MA 01760
USA

Yours faithfully

Sean Hackett
Marks & Clerk

MARKS & CLERK

Patent and Trade Mark Attorneys

European Patent Attorneys
Chartered Patent Attorneys
European Trade Mark Attorneys
Registered Trade Mark Attorneys

Birmingham Office
Alpha Tower
Suffolk Street Queensway
Birmingham B1 1TT

Tel: +44 (0)121 643 5881
Fax: +44 (0)121 606 4766
+44 (0)121 634 2342
birmingham@marks-clerk.com
www.marks-clerk.com

CONFIRMATION

The European Patent Office
Directorate General 2
D-80298 Munich
GERMANY

VST

Our Ref: F011257PMI

12 February 2007

EPO - Munich
46
15. Feb. 2007

Dear Sirs

re: European Patent Applications in the name of Koninklijke Philips Electronics N.V.

We request recordal of the transfer of ownership of the following European patent applications from Koninkiljke Philips Electronics N.V. to Advanced Metrology Systems LLC. To this end, we enclose evidence showing the transfer in respect of each of these rights.

EP04744392.4	EP03813254.4
EP00956190.3	EP04726878.4
EP00949388.3	
EP02733130.5	EP03775753.1

Arrangements have been made to pay the relevant fees from our deposit account.

Yours faithfully

Sean Hackett
Marks & Clerk

NOTICE OF
PATENT AND PATENT APPLICATION ASSIGNMENT

Effective Date: October 5th, 2006

WHEREAS, Koninklijke Philips Electronics N.V., a corporation organized and existing under the laws of The Netherlands ("Assignor"), is the owner of the inventions listed on Schedule A (collectively, the "Inventions") for which applications for United States Patents were filed and issued (collectively, the "Patents" and "Patent Applications"); and

WHEREAS, Advanced Metrology Systems LLC, a limited liability company organized and existing under the laws of the State of Delaware ("Assignee"), is desirous of obtaining the entire right, title and interest in, to and under the Inventions, the Patents , the Patent Applications, and any patents which have been or may be granted therefrom, effective as of the Effective Date hereof; and

WHEREAS, Assignee has entered into a Class A and Class B Units Purchase Agreement by and among Philips Electronics North America Corporation, an affiliate of Assignor ("PENAC"), Philips Advanced Metrology Systems, Inc., another affiliate of Assignor ("PAMS"), JHW Greentree Capital, L.P., Advanced Metrology Systems Holdings LLC ("Holdings LLC") and Assignee dated as of October 5, 2006 (the "Purchase Agreement") pursuant to which Holdings LLC and its subsidiary, the Assignee, have agreed to purchase from PAMS and its affiliates, and PAMS and PENAC have agreed to cause the transfer to Assignee, among other things, all of the Assignor's right, title and interests in the Inventions, the Patents, the Patent Applications, and any patents which have been or may be granted therefrom;

NOW, THEREFORE, in consideration of the premises set forth above and in the Purchase Agreement and for other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged:

1. Assignor hereby sells, assigns, transfers and sets over to Assignee, its successors, legal representatives and assigns, the entire right, title and interest in and to (i) the Inventions, and the Applications and all divisions, renewals and continuations thereof, and all Patents of the United States which have been or may be granted thereon and all reissues and extensions thereof; (ii) all applications for industrial property protection, including, without limitation, all applications for patents, utility models, and designs which may hereafter be filed for the Invention in any country or countries foreign to the United States, together with the right to file such applications and the right to claim for the same the priority rights derived from the Application under the Patent Laws of the United States, the International Convention for the Protection of Industrial Property, or any other international agreement or the domestic laws of the country in which any such application is filed, as may be applicable; and all forms of industrial property protection, including, without limitation, patents, utility models, inventors' certificates and designs which may be granted for the Invention in any country or countries foreign to the United States and all extensions, renewals and reissues thereof; (iii) the right to sue or otherwise recover for any infringements thereof, (iv) all income, royalties, damages and other payments now and hereafter due and/or payable with respect thereto (including, without limitation, payments under all licenses entered into in connection therewith, and damages and payments for past and future infringements thereof).

2. Assignor hereby authorizes and requests the Commissioner of Patents and Trademarks of the United States, and any official of any country or countries foreign to the United States whose duty it is to issue patents or other evidence or forms of industrial property protection on applications as aforesaid, to issue the same to the Assignee, its successors, legal representatives and assigns, in accordance with the terms of this instrument and the Purchase Agreement.

IN WITNESS WHEREOF, the parties hereto have caused this Assignment to be executed by their respective duly authorized representatives as of the Effective Date.

ASSIGNOR:	ASSIGNEE:
Koninklijke Philips Electronics N.V.	Advanced Metrology Systems LLC
By:	By:
Name: Leo van Alphen	Name: Chris Moore
Title: Senior Vice President	Title: Manager
Philips International BV Authorized Signatory for KPENV	

STATE OF New York)
) SS.
COUNTY OF New York)

On this 5th day of October, 2006, before me personally appeared Leo van Alphen to me personally known, who, being by me duly sworn, did say that (s)he is the Authorized Signatory of Koninklijke Philips Electronics N.V., a corporation organized and existing under the laws of The Netherlands, and that said instrument was signed and sealed on behalf of said corporation, by all necessary authority; and said Leo van Alphen acknowledged said instrument to be the free act and deed of said corporation.

In witness whereof, I have hereunto attached my hand and notarial seal, at the County and State aforesaid on the day and year last above written.

(Signature), Notary Public
My Commission Expires:

MARIAN E. GUSTAFSON
Notary Public, State of New York
No. ~~60-4719491~~ 01GU4719491
~~Westchester County~~
Qualified in New York County
Commission Expires 4/15/2010

Country	Patent/ Publication No. (Application No.)	Issue/ Publication Date (Filed Date)	Title	Family (Foreign Filings)
U.S.	60/635,680	12/13/2004	Method and Apparatus for Reducing Probe Wavelength in Laser Excited Surface Acoustic Wave Spectroscopy	(WO IB2005/054142)
U.S.	60/696,831	7/6/05 (provisional application)	Method of Measuring Deep Trenches with Model-Based Optical Spectroscopy	(WOIB2006/052211)
U.S.	5,392,118	2/21/1995	Method for Measuring a Trench Depth Parameter of a Material	
U.S.	5,384,639	1/24/1995	Depth Measurement of High Aspect Ratio Structures	

SCHEDULE A

To Notice of Patent and Patent Application Assignment

Country	Patent/ Publication No. (Application No.)	Issue/ Publication Date (Filed Date)	Title	Family (Foreign Filings)
U.S.	6,393,915	5/28/2002	Method and Device for Simultaneously Measuring Multiple Properties of Multilayer Films	(EP 00956190.3) (JP 01-514559) (WO EP2000/006804)
U.S.	6,587,794	7/1/2003	Method for Measuring Thin Metal Films	(EP 00949388.3) (JP 01-514548) (WO EP2000/006981)
U.S.	6,812,479	11/2/2004	Sample Positioning Method for Surface Optical Diganostics Using Video Imaging	(EP 02733130.5) (JP 03-502436) (WO IB2002/002031)
U.S.	10/484,584	7/26/2002	Opto-Acoustic Apparatus with Optical Heterodyning for Measuring Solid Surfaces and Thin Films	(TW 091117264) (WO EP2002/002918)

Country	Patent/ Publication No. (Application No.)	Issue/ Publication Date (Filed Date)	Title	Family (Foreign Filings)
U.S.	60/433,367	12/13/2003	Method and Apparatus for Measuring Thin Film via Transient Thermoreflectance	(WO IB2003/005882) (CN – no serial no. avail.) (EP – 03775753.1 no serial no. avail.) (JP – no serial no. avail.) (KR – no serial no. avail.) (MY PI20034747)
U.S.	60/433,312 10/548,345	12/13/2003	Method of Determining Properties of Patterned Thin Film Metal Structures Using Transient Thermoresponse	(WO IB2003/005876) (CN – no serial no. avail.) (EP – ~~no serial no. avail.~~) 03813254.4 (JP – no serial no. avail.) (KR – no serial no. avail.) MY PI20034756
U.S.	60/489,629 60/463,259	7/24/2004 4/16/2003	Method for Measuring Thin Films Cross Reference to Related Application	(WO IB2004/001107) (MY PI20041361) EP 04726878.4
U.S.	60/483,099 10/561,467	6/24/2003 6/24/2003	Method of Measuring Sub-Micron Trench Structures	(WO IB2004/050985) (TW 093117975) EP 04744392.4

MARKS & CLERK

Patent and Trade Mark Attorneys

European Patent Attorneys European Trade Mark Attorneys
Chartered Patent Attorneys Registered Trade Mark Attorneys

Fax No:	+498923994465
To:	
Attn:	zzepo, fax
From:	Davies, Bryan J
Subject:	F011257PMI - Registering of transfer fee 04744392.4
Fax Ref:	
Date:	14 February 2007 **at** 11:08
No of pages:	2 *(Inclusive of cover sheet)*

SPECIAL COMMENTS OR MESSAGE

Applicant: Koninklijke Philips Electronics N.V.

Alpha Tower, Suffolk Street Queeensway, Birmingham B1 1TT
Telephone: 0121 -643 5881 Fax: 0121 -606 4766
International Telephone: +44121 -643 5881 International Fax: +44121 -606 4766

Zur Kasse

Payment of fees and costs

European Patent Office
Directorate
Cash and Accounts
D - 80298 München

Please complete using a typewriter or a word processor

Name of payer
MARKS & CLERK (MIDLANDS)

Address
5th FLOOR, ALPHA TOWER,
SUFFOLK STREET QUEENSWAY,
BIRMINGHAM, B1 1TT, ENGLAND

Payer's reference
F011257PMI

Mode of payment

☐ Bank/Giro transfer ❶

☐ Enclosed Cheque No.

☒ Debit from deposit account with the EPO is requested ❷

Deposit account No
28050602

Patent application / Patent No. (A separate form is required for each applicatio

EP 04744392.4 PCT

Code	Fee	Currency	Amount
001	Filing fee	EUR	
002	Search fee	EUR	
005	Designation fee(s)	EUR	
015	Claims fee(s) (Rule 31 (1) EPC)	EUR	
055	Additional copy	EUR	
006	Examination fee	EUR	
007	Fee for grant including fee for printing (up to 35 pages)	EUR	
008	Additional fee for printing (more than 35 pages)	EUR	
033	Renewal fee for the 3rd year	EUR	
034	Renewal fee for the 4th year	EUR	
035	Renewal fee for the 5th year	EUR	
	Extension fee(s) for:	EUR	
022	Registering of transfer	EUR	80
		EUR	
		EUR	
		EUR	
	....	EUR	
		EUR	
	Total	EUR	80

① Payment must be made without charge to the payee. For European Patent Organisation accounts and corresponding currencies of payment see overleaf.
② Debits from deposit accounts with the European Patent Office may only be made in DEM.
③ Payments must be made in the currency of the State in which the EPO account in question is held. Please use the abbreviations for currencies of payment shown overleaf
④ Contracting States should only be specified if they differ from those designed in box 33 of EPO Form 1001 (Request for Grant) or in box V of PCT Form RO/101.
⑤ When extension fees are paid, the States for which they are intended must be specified.

Signature MARKS & CLERK Place, Date 14 February 2007

MARKS & CLERK

Patent and Trade Mark Attorneys

European Patent Attorneys
Chartered Patent Attorneys
European Trade Mark Attorneys
Registered Trade Mark Attorneys

Birmingham Office
Alpha Tower
Suffolk Street Queensway
Birmingham B1 1TT

Tel: +44 (0)121 643 5881
Fax: +44 (0)121 606 4766
+44 (0)121 634 2342
birmingham@marks-clerk.com
www.marks-clerk.com

M. 14.02.07

Our Ref: F011257PMI

The European Patent Office
Directorate General 2
D-80298 Munich
GERMANY

12 February 2007

Dear Sirs

re: **European Patent Applications in the name of Koninklijke Philips Electronics N.V.**

We request recordal of the transfer of ownership of the following European patent applications from Koninkiljke Philips Electronics N.V. to Advanced Metrology Systems LLC. To this end, we enclose evidence showing the transfer in respect of each of these rights.

EP04744392.4	EP03813254.4
EP00956190.3	EP04726878.4
EP00949388.3	
EP02733130.5	EP03775753.1

Arrangements have been made to pay the relevant fees from our deposit account.

Yours faithfully

Sean Hackett
Marks & Clerk

NOTICE OF
PATENT AND PATENT APPLICATION ASSIGNMENT

Effective Date: October 5th, 2006

WHEREAS, Koninklijke Philips Electronics N.V., a corporation organized and existing under the laws of The Netherlands ("Assignor"), is the owner of the inventions listed on Schedule A (collectively, the "Inventions") for which applications for United States Patents were filed and issued (collectively, the "Patents" and "Patent Applications"); and

WHEREAS, Advanced Metrology Systems LLC, a limited liability company organized and existing under the laws of the State of Delaware ("Assignee"), is desirous of obtaining the entire right, title and interest in, to and under the Inventions, the Patents , the Patent Applications, and any patents which have been or may be granted therefrom, effective as of the Effective Date hereof; and

WHEREAS, Assignee has entered into a Class A and Class B Units Purchase Agreement by and among Philips Electronics North America Corporation, an affiliate of Assignor ("PENAC"), Philips Advanced Metrology Systems, Inc., another affiliate of Assignor ("PAMS"), JHW Greentree Capital, L.P., Advanced Metrology Systems Holdings LLC ("Holdings LLC") and Assignee dated as of October 5, 2006 (the "Purchase Agreement") pursuant to which Holdings LLC and its subsidiary, the Assignee, have agreed to purchase from PAMS and its affiliates, and PAMS and PENAC have agreed to cause the transfer to Assignee, among other things, all of the Assignor's right, title and interests in the Inventions, the Patents, the Patent Applications, and any patents which have been or may be granted therefrom;

NOW, THEREFORE, in consideration of the premises set forth above and in the Purchase Agreement and for other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged:

1. Assignor hereby sells, assigns, transfers and sets over to Assignee, its successors, legal representatives and assigns, the entire right, title and interest in and to (i) the Inventions, and the Applications and all divisions, renewals and continuations thereof, and all Patents of the United States which have been or may be granted thereon and all reissues and extensions thereof; (ii) all applications for industrial property protection, including, without limitation, all applications for patents, utility models, and designs which may hereafter be filed for the Invention in any country or countries foreign to the United States, together with the right to file such applications and the right to claim for the same the priority rights derived from the Application under the Patent Laws of the United States, the International Convention for the Protection of Industrial Property, or any other international agreement or the domestic laws of the country in which any such application is filed, as may be applicable; and all forms of industrial property protection, including, without limitation, patents, utility models, inventors' certificates and designs which may be granted for the Invention in any country or countries foreign to the United States and all extensions, renewals and reissues thereof; (iii) the right to sue or otherwise recover for any infringements thereof, (iv) all income, royalties, damages and other payments now and hereafter due and/or payable with respect thereto (including, without limitation, payments under all licenses entered into in connection therewith, and damages and payments for past and future infringements thereof).

2. Assignor hereby authorizes and requests the Commissioner of Patents and Trademarks of the United States, and any official of any country or countries foreign to the United States whose duty it is to issue patents or other evidence or forms of industrial property protection on applications as aforesaid, to issue the same to the Assignee, its successors, legal representatives and assigns, in accordance with the terms of this instrument and the Purchase Agreement.

IN WITNESS WHEREOF, the parties hereto have caused this Assignment to be executed by their respective duly authorized representatives as of the Effective Date.

ASSIGNOR:	**ASSIGNEE:**
Koninklijke Philips Electronics N.V.	Advanced Metrology Systems LLC
By:	By:
Name: Leo van Alphen	Name: Chris Moore
Title: Senior Vice President	Title: Manager
Philips International BV Authorized Signatory for KPENV	

2

STATE OF New York)
) SS.
COUNTY OF New York)

On this 5th day of October, 2006, before me personally appeared Leo van Alphen to me personally known, who, being by me duly sworn, did say that (s)he is the Authorized Signatory of Koninklijke Philips Electronics N.V., a corporation organized and existing under the laws of The Netherlands, and that said instrument was signed and sealed on behalf of said corporation, by all necessary authority; and said Leo van Alphen acknowledged said instrument to be the free act and deed of said corporation.

In witness whereof, I have hereunto attached my hand and notarial seal, at the County and State aforesaid on the day and year last above written.

(Signature), Notary Public
My Commission Expires:

MARIAN E. GUSTAFSON
Notary Public, State of New York
No. ~~60-4715491~~ 01GU4719491
~~Westchester County~~
Qualified in New York County
Commission Expires 4/15/2010

SCHEDULE A

To Notice of Patent and Patent Application Assignment

Country	Patent/ Publication No. (Application No.)	Issue/ Publication Date (Filed Date)	Title	Family (Foreign Filings)
U.S.	6,393,915	5/28/2002	Method and Device for Simultaneously Measuring Multiple Properties of Multilayer Films	(EP 00956190.3) (JP 01-514559) (WO EP2000/006804)
U.S.	6,587,794	7/1/2003	Method for Measuring Thin Metal Films	(EP 00949388.3) (JP 01-514548) (WO EP2000/006981)
U.S.	6,812,479	11/2/2004	Sample Positioning Method for Surface Optical Diganostics Using Video Imaging	(EP 02733130.5) (JP 03-502436) (WO IB2002/00203 1)
U.S.	10/484,584	7/26/2002	Opto-Acoustic Apparatus with Optical Heterodyning for Measuring Solid Surfaces and Thin Films	(TW 091117264) (WO EP2002/00291 8)

Country	Patent/ Publication No. (Application No.)	Issue/ Publication Date (Filed Date)	Title	Family (Foreign Filings)
U.S.	60/433,367	12/13/2003	Method and Apparatus for Measuring Thin Film via Transient Thermoreflectance	(WO IB2003/005882) (CN – no serial no. avail.) (EP – 03775753.1 no serial no. avail.) (JP – no serial no. avail.) (KR – no serial no. avail.) (MY PI20034747)
U.S.	60/433,312 10/548,345	12/13/2003	Method of Determining Properties of Patterned Thin Film Metal Structures Using Transient Thermoresponse	(WO IB2003/005876) (CN – no serial no. avail.) (EP – ~~no serial no. avail.~~) 03813254.4 (JP – no serial no. avail.) (KR – no serial no. avail.) MY PI20034756
U.S.	60/489,629 60/463,259	7/24/2004 4/16/2003	Method for Measuring Thin Films Cross Reference to Related Application	(WO IB2004/001107) (MY PI20041361) EP 04726878.4
U.S.	60/483,099 10/561,467	6/24/2003 6/24/2003	Method of Measuring Sub-Micron Trench Structures	(WO IB2004/050985) (TW 093117975) EP 04744392.4

Country	Patent/ Publication No. (Application No.)	Issue/ Publication Date (Filed Date)	Title	Family (Foreign Filings)
U.S.	60/635,680	12/13/2004	Method and Apparatus for Reducing Probe Wavelength in Laser Excited Surface Acoustic Wave Spectroscopy	(WO IB2005/054142)
U.S.	60/696,831	7/6/05 (provisional application)	Method of Measuring Deep Trenches with Model-Based Optical Spectroscopy	(WOIB2006/052211)
U.S.	5,392,118	2/21/1995	Method for Measuring a Trench Depth Parameter of a Material	
U.S.	5,384,639	1/24/1995	Depth Measurement of High Aspect Ratio Structures	

Received at the EPO on Feb 14, 2007 12:27:50. Page 7 of 7

European Patent Office
80298 MUNICH
GERMANY
Tel.: +49 89 2399 - 0
Fax: +49 89 2399 - 4465

Europäisches Patentamt | **European Patent Office** | **Office européen des brevets**

Hackett, Sean James
Marks & Clerk,
Patent Attorneys,
Alpha Tower,
Suffolk Street Queensway
Birmingham B1 1TT
GRANDE BRETAGNE

Formalities Officer
Name: Conner
Tel.: 2241

Date 08.01.07

Reference	Application No./Patent No.
F074196PEP	04744392.4 - 2204
Applicant/Proprietor	
Koninklijke Philips Electronics N.V.	

Communication of amended entries concerning the representative (Rule 92(1)h) EPC)

As requested, for the above-mentioned European patent application/European patent the entries concerning the representative have been amended as follows:

Hackett, Sean James
Marks & Clerk,
Patent Attorneys,
Alpha Tower,
Suffolk Street Queensway
Birmingham B1 1TT
GB

The amendment will be recorded in the Register of European Patents.

Transfer Service
Tel.: +49 (0)89 2399 2780

Europäisches Patentamt • European Patent Office • Office européen des brevets

MARKS & CLERK

Patent and Trade Mark Attorneys

European Patent Attorneys
Chartered Patent Attorneys
European Trade Mark Attorneys
Registered Trade Mark Attorneys

Birmingham Office
Alpha Tower
Suffolk Street Queensway
Birmingham B1 1TT

Tel: +44 (0)121 643 5881
Fax: +44 (0)121 606 4766
+44 (0)121 634 2342
birmingham@marks-clerk.com
www.marks-clerk.com

European Patent Office
Directorate General 2
Erhardtstrasse 27
D -80298
München
Germany

EPO - Munich
73
14. Dez. 2006

Our Ref: F074196PEP

13 December 2006

Dear Sirs

European Patent Application No. 04744392.4
In the name of Koninklijke Philips Electronics N.V.
For 'Method Of Measuring Sub-Micron Trench Structures'

Please be advised that with immediate effect, the writer has taken over responsibility for this European patent application in place of Julius Simon Cohen of Philips Intellectual Property & Standards.

Yours faithfully

Sean J. Hackett
European Patent Attorney
MARKS & CLERK
E-mail: shackett@marks-clerk.com

EPA/EPO/OEB
D-80298 München
+49 89 2399-0
TX 523 656 epmu d
FAX +49 89 2399-4465

Europäisches Patentamt | **European Patent Office** | **Office européen des brevets**

Generaldirektion 2 | Directorate General 2 | Direction Générale 2

Cohen, Julius Simon
Philips Intellectual Property & Standards,
P.O. Box 220
5600 AE Eindhoven
PAYS-BAS

Telephone numbers:

Primary Examiner (substantive examination) +49 89 2399-2623

Formalities Officer / Assistant (Formalities and other matters) +49 89 2399-0

Application No.	Ref.	Date
04 744 392.4 - 2204	PHUS030190EP1	28.11.2006
Applicant: Koninklijke Philips Electronics N.V.		

Communication pursuant to Article 96(2) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(1) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 78(2) and 83(2) and (4) EPC.

One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (Rule 36(1) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Article 96(3) EPC).

Europäisches Patentamt • European Patent Office • Office européen des brevets

Mason, William
Primary Examiner
for the Examining Division

Enclosure(s): 1 page/s reasons (Form 2906)

Registered Letter
EPO Form 2001 07.02CSX

The examination is being carried out on the **following application documents**:

Description, Pages

1-11 as originally filed

Claims, Numbers

1-16 as originally filed

Drawings, Sheets

1/9-9/9 as originally filed

****

1. An International Preliminary Report on Patentability has already been drawn up for the present application in accordance with the PCT. The deficiencies mentioned in that report give rise to objections under the corresponding provisions of the EPC.

EPA/EPO/OEB
D-80298 München
+49 89 2399 - 0
FAX +49 89 2399 - 4465

Europäisches Patentamt | **European Patent Office** | **Office européen des brevets**

Generaldirektion 2 | Directorate General 2 | Direction Générale 2

MAZNEV, Alexei
P.O. Box 3001
Briarcliff Manor, NY 10510-8001
ETATS-UNIS D'AMERIQUE

Formalities Officer

Name: Conner

Tel.: 2241

Date
08.11.06

Reference	Application No./Patent No.
	04744392.4-2204-IB2004050995
Applicant/Proprietor	
Koninklijke Philips Electronics N.V.	

Notification of the data mentioned in Article 128(5) EPC pursuant to Rule 17(3) EPC

In the above-identified patent application you are designated as inventor/co-inventor.
Pursuant to Rule 17(3) EPC the data as mentioned in Article 128(5) EPC are notified herewith:

DATE OF FILING	: 23.06.04
PRIORITY	: US/24.06.03/ USP 482099 : US/31.03.04/ USP 558071
TITLE	: METHOD OF MEASURING SUB-MICRON TRENCH STRUCTURES
DESIGNATED STATES	: AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PL PT RO SE SI SK TR

RECEIVING SECTION

Europäisches Patentamt • European Patent Office • Office européen des brevets

Europäisches Patentamt
European Patent Office
Office européen des brevets

PRIORITY
PRIORITAIRE

TNT Post
Port betaald
Port Payé
Pays-Bas

EPA EPO OEB
tel.: (070) 3404616

28 N[illegible]

Mailroom V

RETURN TO SENDER

NO LONGER AT THIS ADDRESS ☐

UNKNOWN AT THIS ADDRESS ☐

4.111

10510+8001 8050 [redacted]

P.B.5818 - Patentlaan 2
2280 HV Rijswijk (ZH)
☎ (070) 3 40 20 40
FAX (070) 3 40 30 16

Europäisches Patentamt | **European Patent Office** | **Office européen des brevets**

Generaldirektion 1 | Directorate General 1 | Direction générale 1

Cohen, Julius Simon
Philips Intellectual Property & Standards,
P.O. Box 220
5600 AE Eindhoven
PAYS-BAS

EPO Customer Services

Tel.: +31 (0)70 340 45 00

Date
15.02.06

Reference	Application No./Patent No.
PHUS030190EP	04744392.4 - 2204 PCT/IB2004050985
Applicant/Proprietor	
Koninklijke Philips Electronics, N.V.	

Notification of European publication number and information on the application of Article 67(3) EPC

The provisional protection under Article 67(1) and (2) EPC in the individual contracting states becomes effective only when the conditions referred to in Article 67(3) EPC have been fulfilled (for further details, see information brochure of the European Patent Office "National Law relating to the EPC" and additional information in the Official Journal of the European Patent Office).

Pursuant to Article 158(1) EPC the publication under Article 21 PCT of an international application for which the European Patent Office is a designated Office takes the place of the publication of a European patent application.

The bibliographic data of the above-mentioned Euro-PCT application will be published on 29.03.06 in Section I.1 of the European Patent Bulletin. The European publication number is 1639344.

In all future communications to the European Patent Office, please quote the application number plus Directorate number.

Receiving Section

Europäisches Patentamt • European Patent Office • Office européen des brevets

P.B.5818 - Patentlaan 2
2280 HV Rijswijk (ZH)
☏ (070) 3 40 20 40
FAX (070) 3 40 30 16

Europäisches Patentamt | **European Patent Office** | **Office européen des brevets**

Generaldirektion 1 | Directorate General 1 | Direction générale 1

Cohen, Julius Simon
Philips Intellectual Property & Standards,
P.O. Box 220
5600 AE Eindhoven
PAYS-BAS

EPO Customer Services

Tel.: +31 (0)70 340 45 00

Date
09-02-2006

Reference	Application No./Patent No.
PHUS030190EP	04744392.4 - 2204 PCT/IB2004050985
Applicant/Proprietor	
Koninklijke Philips Electronics N.V.	

Communication pursuant to Rules 109 and 110 EPC

(1) Amendment of application documents, especially the claims (R. 109 EPC)

The above mentioned international (Euro-PCT) application has entered the European phase, or can do so, once the necessary conditions are fulfilled.

Under Articles 28, 41 PCT, Rules 52, 78 PCT and Rule 86(2) to (4) EPC, the applicant may amend the application documents after receiving the international search report.

Whether or not he has already done so, he now has a further opportunity to file amended claims or other application documents within a non-extendable time limit of one month after notification of the present communication (R. 109 EPC).

The claims applicable on expiry of the above time limit, i.e. those filed on entry into the European phase or in response to the present communication, will form the basis for the calculation of any claims fee to be paid (see page 2) and for any supplementary search to be carried out under Article 157(2) EPC (R. 109 EPC).

--2/

Registered letter

(2) Claims fees under Rule 110 EPC

If the application documents on which the European grant procedure is to be based comprise more than ten claims, a claims fee shall be payable for the eleventh and each subsequent claim within the period provided for in Rule 107(1) EPC.

☐ Based on the application documents currently on file, all necessary claims fees have already been paid (or the documents do not comprise more than 10 claims).

☑ All necessary fees will be/have been debited automatically according to the automatic debit order.

☐ The claims fees due for the claims .... to .... were not paid within the above-mentioned period.

Any non-paid claims fee, either based on the current set of claims or on any amended claims to be filed pursuant to Rule 109 EPC (see page 1), may still be validly paid within a non-extendable period of grace of **one month** after notification of this communication.

If a payment is made for only some of the claims, it must be indicated for which claims it is intended. If a claims fee is not paid in due time, the claim concerned is deemed to be abandoned (R. 110(4) EPC).

If claims fees have already been paid, but on expiry of the above-mentioned time limit there is a new set of claims containing fewer fee-incurring claims than previously, the claims fees in excess of those due under Rule 110(2), 2nd sentence, EPC will be refunded (R. 110(3) EPC).

You are reminded that any supplementary search under Article 157(2) EPC will relate only to the last set of claims applicable on expiry of the above time limit AND will be confined to those fee-incurring claims for which fees have been paid in due time.

The fee for the eleventh and each subsequent claim is EUR 40,00.

Receiving Section

Jensen, Pernille

Europäisches Patentamt • European Patent Office • Office européen des brevets

To the European Patent Office

Entry into the European phase (EPO as designated or elected Office)

European application number	
PCT application number	PCT/IB2004/050985
PCT publication number	
Applicant's or representative's reference	PHUS030190EP

1. Applicant

Particulars of the applicant(s) are contained in the international publication or were recorded by the International Bureau subsequent to the international publication.	☑
Changes which have not yet been recorded by the International Bureau are set out here:	☐
Address for correspondence	

2. Representative 1

This is the representative who will be listed in the Register of European Patents and to whom notifications will be made	
Name	COHEN, Julius, S.
Address of place of business	Philips Intellectual Property & Standards P.O. Box 220 NL-5600 AE Eindhoven Netherlands
Telephone	+31 40 2743505
Fax	+31 40 2743489
e-mail	
Any additional representative(s) is/are listed here:	☐

3. Authorisation

An individual authorisation is attached.	☐
A general authorisation has been registered under No:	☐
A general authorisation has been filed, but not yet registered.	☐
The authorisation filed with the EPO as PCT receiving Office expressly includes the European phase.	☐

4. Request for examination

Examination of the application under Art. 94 EPC is hereby requested. The examination fee is being (has been, will be) paid.	☑
Request for examination in an admissible non-EPO language:	☑ Verzocht wordt om onderzoek van de aanvrage als bedoeld in Art. 94.

5. Copies

One or more additional sets of copies of the documents cited in the supplementary European search report are hereby requested. ☐

Number of additional sets of copies

6. Documents intended for proceedings before the EPO

6.1 Proceedings before the EPO as designated Office (PCT I) are to be based on the following documents:

the application documents published by the International Bureau (with all claims, description and drawings), where applicable with amended claims under Art. 19 PCT ☑

unless replaced by the amendments attached. ☐

Where necessary, clarifications should be attached as 'Other Documents'

6.2 Proceedings before the EPO as elected Office (PCT II) are to be based on the following documents:

the documents on which the international preliminary examination report is based, including any annexes ☑

unless replaced by the amendments attached. ☐

Where necessary, clarifications should be attached as 'Other Documents'

If the EPO as International Preliminary Examining Authority has been supplied with test reports, these may be used as the basis of proceedings before the EPO. ☑

7. Translations

Translations in one of the official languages of the EPO (English, French, German) are attached as crossed below:

- *In proceedings before the EPO as designated or elected Office (PCT I + II):*

Translation of the international application (description, claims, any text in the drawings) as originally filed, of the abstract as published and of any indication under Rule 13bis.3 and 13bis.4 PCT regarding biological material ☐

Translation of priority application(s) ☐

It is hereby declared that the international application as originally filed is a complete translation of the previous application (Rule 38(5) EPC) ☐

- *In addition, in proceedings before the EPO as designated Office (PCT I):*

Translation of amended claims and any statement under Art. 19 PCT, if the claims as amended are to form the basis for the proceedings before the EPO (see Section 6). ☐

- *In addition, in proceedings before the EPO as elected office (PCT II):*

Translation of annexes to the international preliminary examination report ☐

8. Biological material

The invention relates to and/or uses biological material deposited under Rule 28 EPC. ☐

The particulars referred to in Rule 28(1)(c) EPC (if not yet known, the depository institution and the identification reference(s) [number, symbols, etc.] of the depositor) are given in the international publication or in the translation submitted under Section 7 on: ☐

page(s) / line(s)

A copy of the receipt(s) of deposit issued by the depositary institution

is attached ☐

will be filed at a later date ☐

A waiver of the right to an undertaking from the requester pursuant to Rule 28(3) EPC is attached. ☐

9. Nucleotide and amino acid sequences

The items required under Rules 5.2 and 13ter PCT and Rule 111(3) EPC have already been furnished to the EPO. ☐

The sequence listing as part of the description is attached in PDF format. ☐

The sequence listing does not include matter that goes beyond the content of the application as filed. ☐

In addition, the sequence listing data is attached in computer-readable form in accordance with WIPO Standard 25. ☐

The sequence listing data in computer-readable form in accordance with WIPO Standard 25 is identical to the sequence listing in PDF format. ☐

10. Designation fees

10.1 It is currently intended to pay seven times the amount of the designation fee. The designation fees for all the EPC contracting states designated in the international application are thereby deemed to have been paid (Art. 2 No. 3 RFees). ☑

AT BE BG CH&LI CY CZ DE DK EE ES FI FR GB GR HU IE IT LU MC NL PL PT RO SE SI SK TR

10.2 The declaration in No. 10.1 does not apply. Instead, it is currently intended to pay fewer than seven designation fees for the following EPC contracting states designated in the international application: ☐

It is requested that no communications under Rule 108(3) EPC be issued in respect of any contracting states not indicated.

10.3 If an automatic debit order has been issued (Section 12), the EPO is authorised, on expiry of the basic period under Rule 107(1)(d) EPC, to debit seven times the amount of the designation fee. If states are indicated in No. 10.2, the EPO will debit designation fees for those states only, unless instructed otherwise before the basic period expires. ☑

11. Extension of the European patent

This application is also considered as being a request for extension to all the non-contracting states to the EPC designated in the international application with which "extension agreements" were in force on the date of filing the international application. However, the extension only takes effect if the prescribed extension fee is paid.	☑
It is currently intended to pay the extension fee for the following states:	

12. Automatic debit order ☑

Currency	EUR
The EPO is hereby authorised, under the Arrangements for the automatic debiting procedure, to debit from the deposit account below any fees and costs falling due. For designation fees, see "States".The EPO is also authorised, on expiry of the basic period for paying the extension fees, to debit those fees for each of the "extension states" indicated in "States",	
Deposit account number	28090021
Account holder	Philips International B.V. - IP&S

13. Reimbursements (if any) should be made to the following EPO deposit account: ☑

Number and account holder	28090021, Philips International B.V. - IP&S

14. Fees

		Factor applied	Fee schedule	Amount to be paid
14-1	002 Search fee	0	690.00	0.00
14-2	015 Claims fee	0	40.00	0.00
14-3	020 Basic national fee for an international application	1	90.00	90.00
14-4	033 Renewal fee for the 3rd year	1	380.00	380.00
	Total:		**EUR**	**470.00**

15. Annotations

16. Signature(s) of applicant(s) or representative

Place:	**Eindhoven**
Date:	**28 September 2005**
Signed by:	**Subject: NL, Philips IP&S, J. van der Veer 1086** **Issuer: , European Patent Office, European Patent Office CA**
Capacity:	**(Representative)**

For employees (Art. 133(3) EPC) having a general authorisation:
General authorisation No.

Europäisches Patentamt | European Patent Office | Office européen des brevets

Acknowledgement of receipt

We hereby acknowledge receipt of the form for entry into the European phase (EPO as designated or elected Office) as follows:

Submission number	70758	
PCT application number	PCT/IB2004/050985	
Date of receipt	28 September 2005	
Your reference	PHUS030190EP	
Applicant		
Country		
Documents submitted	EPF1200.PDF ep-euro-pct.xml	application-body.xml package-data.xml
Submitted by	CN=J. van der Veer 1086,O=Philips IP&S,C=NL	
Method of submission	Online	
Date and time receipt generated	28 September 2005, 10:22:12	
Digest	78:71:08:4C:0E:7C:45:D3:61:68:82:8D:F5:D0:62:FD:16:A3:4B:D4	

/European Patent Office/

PCT/IB04/50385

REC'D 9 AUG 2004
WIPO PCT

PA 1202313

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

August 04, 2004

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: ***60/558,071***
FILING DATE: ***March 31, 2004***

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

P. R. Grant

P. R. GRANT
Certifying Officer

Please type a plus sign (+) inside this box → [+]

PTO/SB/16 (02-01)
Approved for use through 10/31/2002. OMB 0651-0032
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

Express Mail Label No. EV 312 069 278 | DATE OF DEPOSIT: 31 MARCH 2004

22154 U.S. PTO 60/558071

033104 17707 U.S. PTO

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Alexei	MAZNEV	Marblehead, Massachusetts, US

☐ *Additional inventors are being named on the _____ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

METHOD OF MEASURING SUB-MICRON TRENCH STRUCTURES

CORRESPONDENCE ADDRESS

Direct all correspondence to:

☒ Customer Number: 24737 → *Place Customer Number Bar Code Label here*

OR *Type Customer Number here*

☐ Firm or Individual Name	PHILIPS ELECTRONICS NORTH AMERICA CORPORATION				
Address	P.O. BOX 3001				
Address					
City	BRIARCLIFF MANOR	State	NY	ZIP	10510-8001
Country	USA	Telephone	914-333-9627	Fax	914-332-0615

ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* 15 ☐ CD(s), Number ____

☒ Drawing(s) *Number of Sheets* 7 ☐ Other (specify) ____

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☐ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees

☒ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 14-1270

☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($): 160

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____.

Respectfully submitted,
SIGNATURE [signature] Date 31 MARCH 2004

TYPED or PRINTED NAME AARON WAXLER REGISTRATION NO. *(if appropriate)* 48,027

TELEPHONE 914 333-9608 Docket Number: US030190

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

PATENT APPLICATION SERIAL NO. ____________________

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

/02/2004 BSAYASI1 00000038 141270 60558071

FC:1005 160.00 DA

PTO-1556
(5/87)

*U.S. Government Printing Office: 2002 — 489-267/69033

METHOD OF MEASURING SUB-MICRON TRENCH STRUCTURES

FIELD OF THE INVENTION

The invention relates to the field of optoacoustic metrology to determine properties of a sample, e.g., a trench structure fabricated on a silicon wafer.

BACKGROUND AND SUMMARY OF THE INVENTION

Fabrication of microelectronic devices typically includes multiple patterning steps wherein trench structures (i.e., holes or linear trenches) are fabricated, typically by etching, in a semiconductor substrate or thin film layers deposited on the substrate.

Non-contact optical methods of measuring such structures are in great demand for industrial process monitoring and control. Parameters of most interest for process control applications can include depth, width, and other parameters of the trench structures. In the state-of-the art integrated circuit manufacturing, typical width of the trench structures is of the order of 0.1μm, while the depth of the trenches may range from under 1 μm to a few microns or more. Non-destructive measurement of such narrow high aspect ratio structures is a challenging problem.

In one known method, described in the prior art U.S.

Patents 5,812,261, 6,081,330, 6,188,478, herein incorporated by reference, a thin film structure is probed using an impulsive stimulated thermal scattering (ISTS) surface acoustic wave spectrometer. As shown in Fig. 1, in this technique, the sample structure 1 is excited with a short pulse of laser light imaged to form a grating pattern 10 on the sample surface by the interference of two beams 3,3′. Absorption of light under each of the bright stripes of the grating pattern 10 causes local heating of the sample, which results in sudden periodic expansion launching acoustic waves at the sample surface. The acoustic wave propagation can be seen in enlarged portion 8. As this surface acoustic wave (SAW) propagates in the plane of the film, it also modulates the diffracted signal beam 6′ intensity, resulting in an oscillatory component (henceforth "acoustic component") in the detected signal.

The above-described technique has been employed to measure the thickness of film layers by analysis of the SAW frequency spectrum.

If a film is patterned, i.e., by etching, ISTS is useful for measuring the etch depth if the size of the etched area is large compared to the SAW wavelength (i.e., typically 2-10 μm). This prior art method will not work for measurement of a surface profile of a bulk sample, such as a silicon wafer. In addition, it is the smaller features (i.e., on the order of 0.1 μm) that

are most likely to be misprocessed during lithography and etching. Consequently, these relatively small features require process control metrology.

In one extension of the ISTS technique described in U.S. patent 6,256,100, the method described above is applied to measure the effective thickness of composite structures formed of narrow (i.e. micron or submicron width) trenches etched in dielectric material and filled with metal. However, this method had not been applied to measuring trench structures prior to metal filling.

In addition, no studies have been done for high-aspect-ratio sub-micron structures which are of the most interest for practical applications.

Accordingly, it would be desirable to provide a method that can measure trench structures on the order of 0.1 μm in width.

The present invention meets the need for a method that can measure trench structures on the order of 0.1 μm at least in one aspect. In one aspect, a method measures a patterned structure. One step of the method is exciting the structure by irradiating it with a spatially periodic laser intensity pattern in order to generate surface acoustic waves. Other steps are diffracting a probe laser beam off a thermal grating to form a signal beam; detecting the signal beam as a function of time to generate a signal waveform; and determining at least one property of the

patterned structure based on the effect of the surface profile on surface acoustic wave phase velocity.

In one embodiment, the spatially periodic laser intensity pattern has a period ranging from 1 to 20 microns. In another embodiment, the patterned structure has a surface profile with a period equal to or less than approximately 2 μm.

In one embodiment, the patterned structure is a periodic array of trenches. In another embodiment, the periodic array is a periodic array of linear trenches. In yet another embodiment, the periodic array is a two-dimensional array of trenches.

In one embodiment, the trenches are fabricated in a silicon substrate. In another embodiment, the trenches are fabricated in a thin film.

In one embodiment, the at least one property is trench depth. In another embodiment, the at least one property is trench width. In another embodiment, the at least one property is a depth profile of the trench structure.

In one embodiment, the determining step includes combining measurements at multiple acoustic wavelengths to determine multiple parameters of the trench structure. In another embodiment, the determining step includes measurements along and across the linear trench structure to determine both trench depth and width. In still another embodiment, the determining step includes measurements both within and outside the patterned

area in order to separate the effect on the surface acoustic wave velocity caused by the trench structures from the other effects such as film thickness.

In one embodiment, the determining step includes analysis of the signal waveform with a theoretical model based on elastic properties of the structure. In another embodiment, the determining step includes analysis of the signal waveform with an empirical calibration.

The invention provides many advantages that are evident from the following description, drawings, and claims.

BRIEF DESCRIPTION OF THE DRAWING

The invention may be more completely understood in reference to the following figures:

Fig. 1 depicts a thin film structure on an integrated circuit probed using impulsive stimulated thermal scattering according to a prior art method;

Fig. 2a depicts a patterned film on a silicon substrate;

Fig. 2b depicts a patterned silicon substrate;

Fig. 3 depicts a matrix indicating calculated dependence of the SAW velocity on trench depth in silicon;

Fig. 4 depicts a matrix indicating calculated dependences of the SAW velocity on trench depth for 1 μm-thick thermal oxide film on a silicon substrate;

Fig. 5 depicts a structure including a silicon substrate, a trench array etched in a SiO_2 film, and a metal film coating;

Fig. 6 depicts signal waveforms generated outside of the patterned area of a sample depicted in Fig.5, parallel to the trenches of a trench array, and perpendicular to the trenches;

Fig.7 depicts a table listing SAW velocity values obtained from the signal waveforms shown in Fig.6.

DETAILED DESCRIPTION OF THE INVENTION

According to the current invention, ISTS can be used to measure trench structures with near- or sub-micron width, e.g. a periodic array of trenches etched either in a thin film or in a silicon substrate. The measurement is based on the fact that the SAW phase velocity is affected by the trench structure and is dependent on the parameters of the structure.

According to the invented method, the excitation and detection of SAWs is performed on a patterned sample with surface profile characterized by a period of the order or less than 1 μm. The measurement yields the SAW frequency at a defined wavelength, from which the SAW phase velocity is calculated. The data are analyzed with the help of an analytical or empirical model to determine a parameter of the profile, typically the trench depth or width.

Accurate analysis of SAW propagation in high aspect ratio trench structures will require finite element calculations. An approximate model can be used in order to obtain an estimate of the effect of high aspect ratio trench array on SAW propagation. The model applies to periodic arrays of linear trenches, such as those labeled 30 and 40 in Fig. 2, with the surface acoustic wave 2 period large compared to the period of the trench structure. Structure (a) of Fig. 2 depicts a periodic array of trenches 30 formed in a thin layer 60 over a substrate 70. Structure (b) of Fig. 2 depicts a periodic array of trenches 40 formed in a silicon substrate. Structure (a) includes a trench 9 on the order of tens of microns. This can be measured by a prior art ISTS method.

The model assumes that if the period of the structure (a) or (b) is small with respect to both SAW 2 wavelength and thickness of the structure, it can be treated as a homogeneous material with effective elastic properties. It is known to calculate the effective elastic properties of a layered structure from the properties of constituent materials, such as in structure (a). The layered structure is effectively described as a transversely isotropic medium with the symmetry axis perpendicular to the layers, which is described by 5 independent effective elastic constants. The same method can be applied to a trench array 30, 40 if vacuum is treated as one of

the constituent materials of the structure. Thus, the following equations expressing effective density ρ^* and elastic constants C_{ij}^* of the trench array through the density ρ and elastic constants C_{ij} of the material can be obtained:

$$\begin{aligned}
&\rho^* = h\rho \\
&C_{11}^* = h\left(C_{11} - \frac{C_{12}^2}{C_{11}}\right) \\
&C_{66}^* = hC_{44} \\
&C_{13}^* = C_{33}^* = C_{44}^* = 0
\end{aligned} \qquad (1)$$

where h is the ratio of the space between the trenches to the period of the structure. It can be expressed trough the trench width/space ratio as h=1/(1+w/s). The notations in equation (1) assume that the z-axis is perpendicular to the trenches.

Fig. 3 presents the calculated dependence of the SAW velocity on the trench depth for trench arrays with width/space ratios 1:1 and 1:3 fabricated in Si. Fig. 4 depicts the calculated dependence of the SAW velocity on the trench depth for trench arrays in a 1 μm-thick silicon dioxide film on Si. The calculations show that there is a significant dependence of the SAW velocity on both the trench depth 80 and width/space ratio, particularly for SAW propagation across the trenches. In order to estimate the repeatability of the trench depth 80 measurements, assume that the repeatability of the SAW velocity measurements are ~0.5 m/s (which corresponds to the frequency

measurement repeatability of 0.1 MHz). For a trench depth of 5000 Å and SAW propagation perpendicular to the trenches, the results presented in Figs. 3 and 4 yield a repeatability estimate of ~7 Å (or 0.14%) for 1:1 width/space ratio trenches in Si and ~20Å (or 0.4%) for trenches in the oxide film.

It should be noted that variations in trench depth 80 and width 90 have different effects on SAW velocity parallel (||) and perpendicular (⊥) to the trenches 5. An increase in the trench width 90 increases the parallel velocity but decreases the perpendicular velocity while an increase in the trench width/space ratio increases the SAW velocity in both directions. This fact indicates that the measurements with SAW propagation along and across the trenches 5 can be combined in order to determine both trench depth 80 and width ratio.

Although the model calculations above applied to a one-dimensional array of linear trenches, it is expected that two-dimensional array of holes will also have an effect of a on the SAW velocity that can be used to measure the parameters of the structure such as trench depth and width.

Performing measurements at multiple SAW wavelengths will provide additional information that can be used for simultaneous measurements of multiple parameters of trench structures. For example, if the SAW wavelength is small compared to the trench depth, SAW velocity will be independent on the trench depth, but

still sensitive to the trench width. At longer wavelength, SAW velocity will be sensitive to both trench depth and width. Combining the measurements at short and long wavelengths will thus allow to measure both parameters simultaneously.

To test the capability of trench measurements with the invented method experimentally, we performed measurements on a structure depicted in Fig. 5 at a SAW wavelength 6 μm. The structure of Fig. 5 includes a substrate 700 formed of silicon, a trench array 500 fabricated in an 800 nm-thick layer of SiO_2. The trench width was 1 μm and the width/space ratio was 1:1. The structure was coated with a ~25 nm of Ta and ~100 nm of Cu 600.

Fig. 6 presents the signal waveforms 600 obtained in the unpatterned area of the sample and on the trench array 601, 602 of Fig. 5 with SAW propagation parallel (e.g., 601) and perpendicular (e.g., 602) to the trenches 5. It can be seen from the waveforms 600, 601, 602, that for the perpendicular propagation, the effect of the surface relief on the signal is particularly strong and that it causes a significant decrease in the SAW frequency.

Fig.7 presents a table listing SAW velocity values obtained from the waveforms shown in Fig.6. One can see that for the parallel propagation, the SAW velocity increases slightly compared to unpatterned area (i.e. zero trench depth), while for perpendicular propagation the velocity decreases significantly.

These results qualitatively agree with the theoretical predictions according to Fig.4.

The invention provides many additional advantages that are evident from the description, drawings, and claims.

The preceding expressions and examples are exemplary and are not intended to limit the scope of the claims that follow.

What is claimed is:

1. A method for measuring a patterned structure (3) comprising:

exciting the structure (3) by irradiating it with a spatially periodic laser intensity pattern in order to generate surface acoustic waves.

diffracting a probe laser beam (6) off the thermal grating to form a signal beam;

detecting the signal beam as a function of time to generate a signal waveform; and

determining at least one property of the patterned structure based on the effect of the surface profile on surface acoustic wave phase velocity.

2. The method of Claim 1, wherein the exciting step further comprises a spatially periodic laser intensity pattern having a period ranging from 1 to 20 microns.

3. The method of Claim 1, wherein the patterned structure is comprised of trenches equal to or less than approximately 2 μm in width.

4. The method of Claim 3, wherein the patterned structure further comprises a periodic array of trenches.

5. The method of Claim 4, wherein the patterned structure further comprises a periodic array of linear trenches.

6. The method of Claim 4, wherein the patterned structure further comprises a two-dimensional periodic array of trenches.

7. The method of Claim 4, wherein the trenches are fabricated in a silicon substrate.

8. The method of Claim 3, wherein the trenches are fabricated in a thin film.

9. The method of Claim 1, wherein the at least one property comprises trench depth.

10. The method of Claim 1, wherein the at least one property comprises trench width.

11. The method of Claim 1, wherein the at least one property comprises a depth profile of the trench structure.

12. The method of Claim 1, wherein the determining step further comprises combining measurements at multiple acoustic

wavelengths to determine multiple parameters of the trench structure.

13. The method of Claim 5, wherein the determining step further comprises combining measurements along and across the trench structure to determine both trench depth and width.

14. The method of Claim 1, wherein the determining step further comprises combining measurements within and outside the patterned area to separate the effect on the surface acoustic wave velocity caused by the trench structure from the other effects such as film thickness.

15. The method of claim 1, wherein the determining step comprises analysis of the signal waveform with a theoretical model based on elastic properties of the structure.

16. The method of Claim 1, wherein the determining step comprises analysis of the signal waveform with a model based on an empirical calibration.

ABSTRACT

The present invention uses ISTS to measure trenches with near- or sub-micron width. The trenches can be etched in a thin film on in a silicon substrate. One step of the method is exciting the structure by irradiating it with a spatially periodic laser intensity pattern in order to generate surface acoustic waves. Other steps are diffracting a probe laser beam off the thermal grating to form a signal beam; detecting the signal beam as a function of time to generate a signal waveform; determining surface acoustic wave phase velocity from the waveform; and determining at least one property of the trench structures based on the dependence of surface acoustic wave phase velocity on the parameters of the structure.

(Fig. 2)

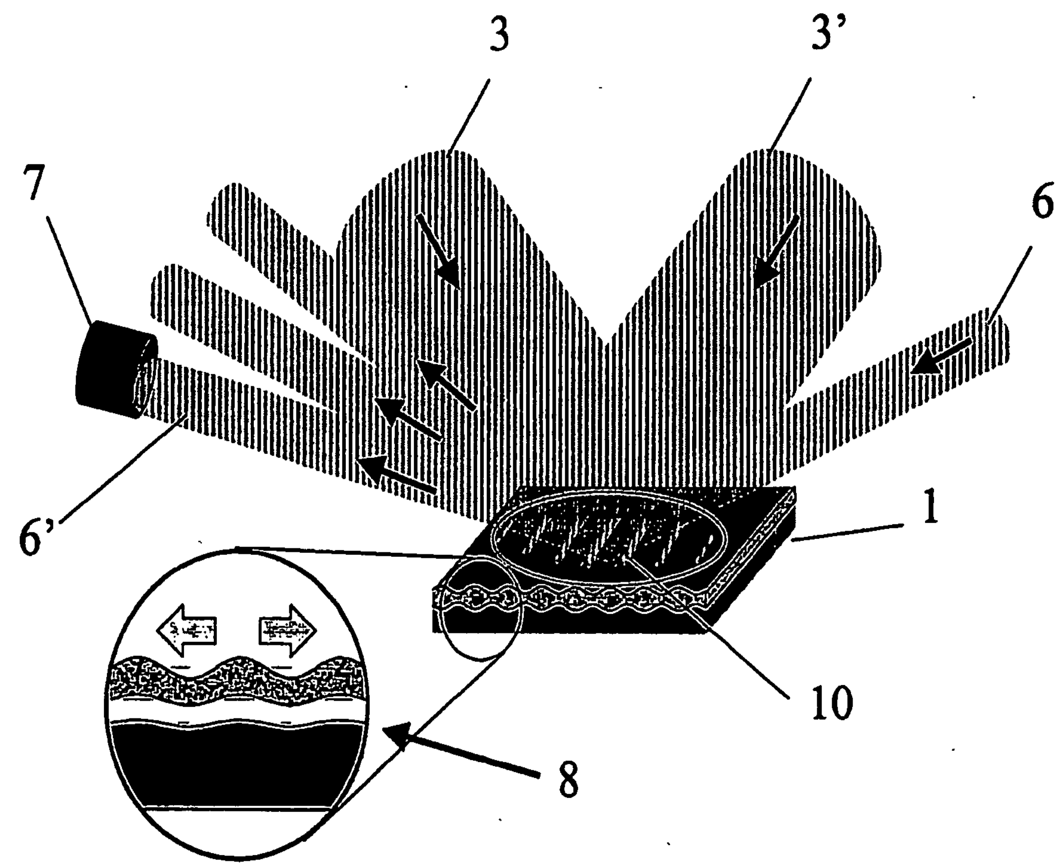

Fig. 1
PRIOR ART

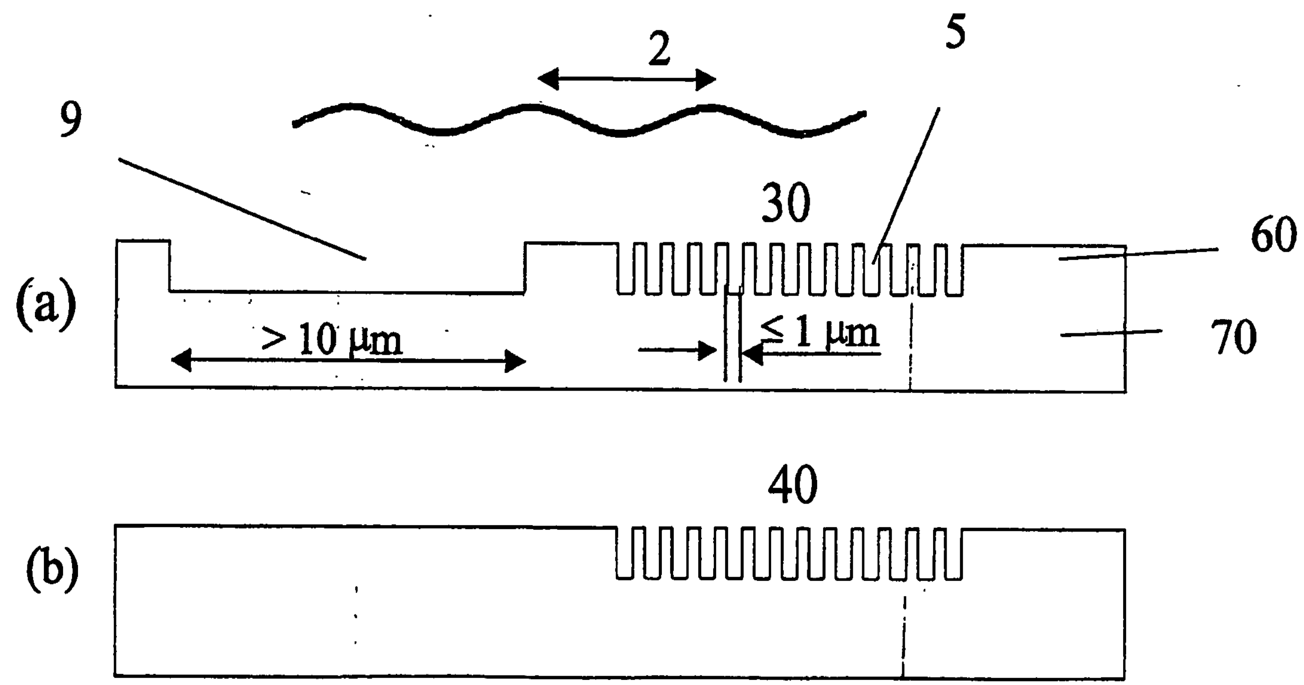

Fig. 2

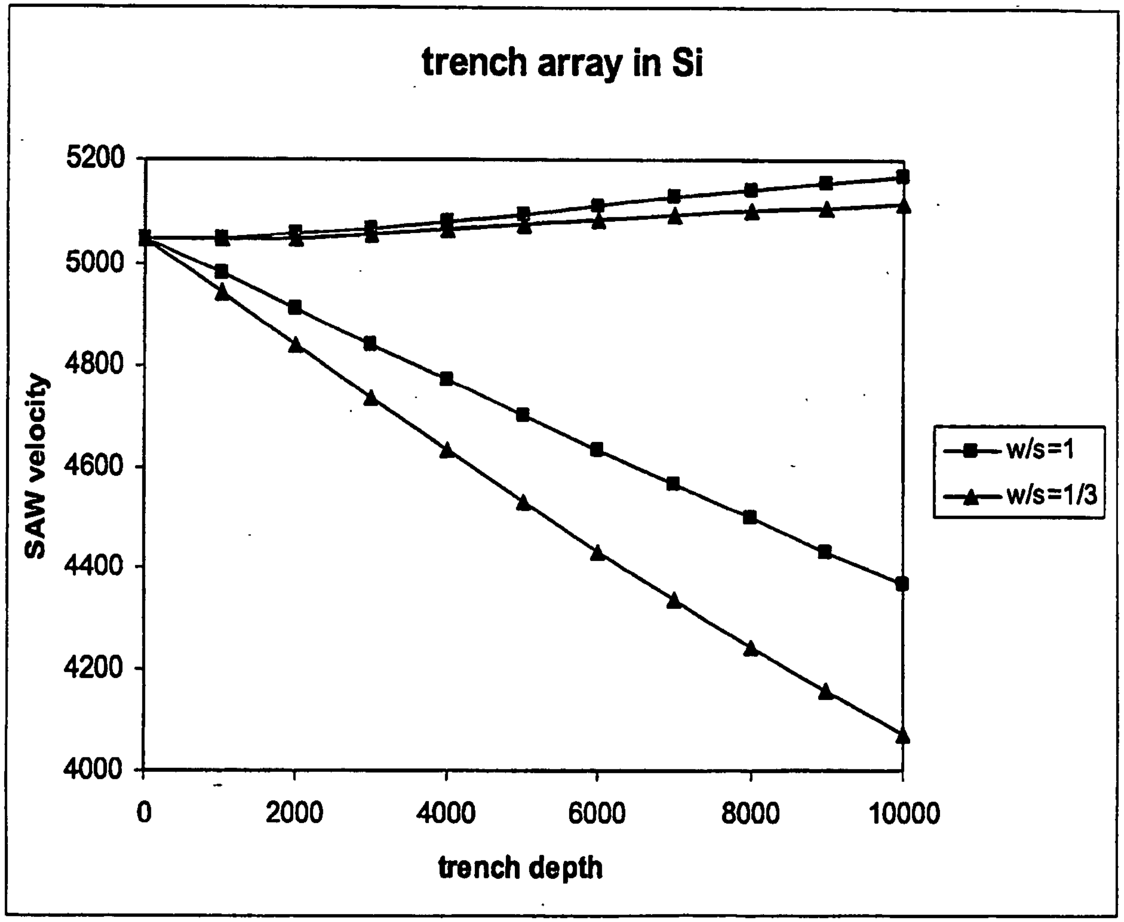
trench array in Si
SAW velocity
5200
5000
4800
4600
4400
4200
4000
0
2000
4000
6000
8000
10000
trench depth
w/s=1
w/s=1/3

Fig. 3

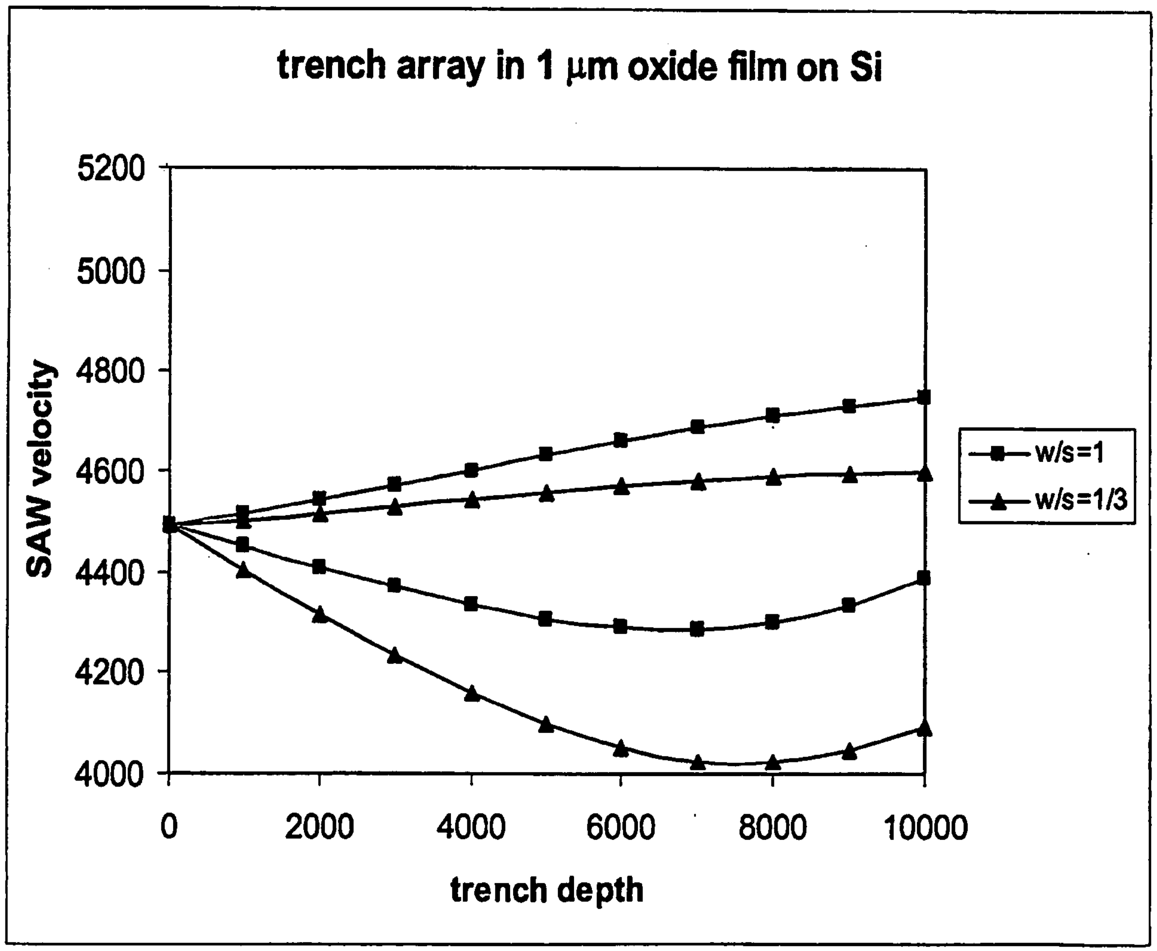
trench array in 1 μm oxide film on Si
SAW velocity
5200
5000
4800
4600
4400
4200
4000
0
2000
4000
6000
8000
10000
trench depth
w/s=1
w/s=1/3

Fig. 4

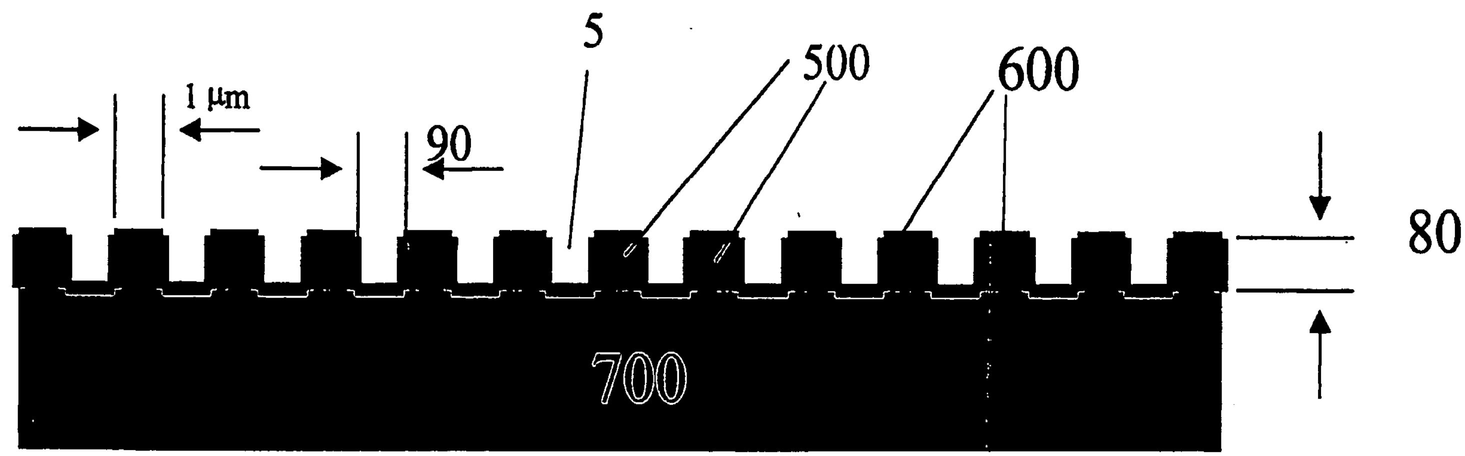

Fig. 5

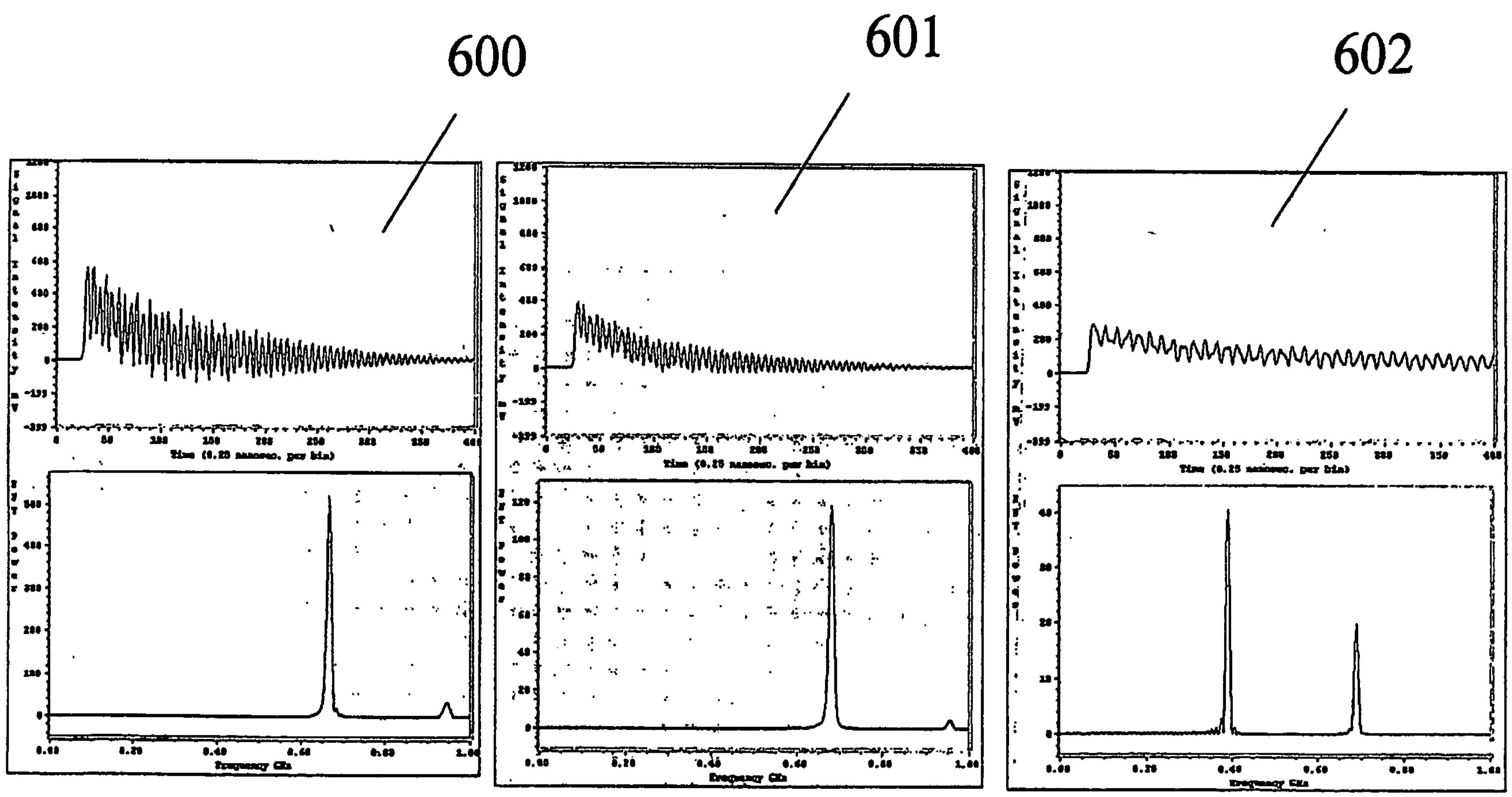

Fig. 6

measurement location	SAW velocity (m/s)
unpatterned area	3930
trench array, parallel	4016
trench array, perpendicular	2299

Fig.7

PCT/IB04/50985

50/201 90

REC'D 16 AUG 2004

WIPO PCT

PA 1177286

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

June 02, 2004

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: *60/482,099*
FILING DATE: *June 24, 2003*

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

H. L. Jackson

H. L. JACKSON
Certifying Officer

PATENT APPLICATION SERIAL NO. ______________

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

06/26/2003 SDENBOB1 00000098 141270 60482099

01 FC:1005 160.00 DA

PTO-1556
(5/87)

*U.S. Government Printing Office: 2002 — 489-267/69033

PROVISIONAL APPLICATION COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION under 37 CFR 1.53(b)(2).

Docket Number US030190		Type a plus sign (+) inside this box	+

INVENTOR(s)/ APPLICANT(s)

LAST NAME	FIRST NAME	MIDDLE INITIAL	RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY)
Maznev	Alexei		Marblehead, MA

TITLE OF THE INVENTION (280 characters max)

OPTOACOUSTIC METHOD FOR MEASURING SURFACE PROFILE ON STRUCTURES CHARACTERIZED BY SUB-MICRON LATERAL FEATURE SIZE

CORRESPONDENCE ADDRESS

Philips Intellectual
Property & Standard
345 Scarborough Road
P.O. Box 3001
Briarcliff Manor, NY 10510-8001

STATE	New York	ZIP CODE	10510	COUNTRY	U.S.A.

ENCLOSED APPLICATION PARTS (check all that apply)

X	Specification	Number of Pages	10		Small Entity Statement
X	Drawing(s)	Number of Sheets	2		Other (specify)

METHOD OF PAYMENT (check one)

	A check or money order is enclosed to cover the Provisional filing fees	PROVISIONAL FILING FEE AMOUNT ($)	$160.00
X	The Commissioner is hereby authorized to charge filing fees and credit Deposit Account Number: 14-1270		

S:\WX\PHUS\US030190-DPROV.doc

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[x] No ,

[ ] Yes, the name of the U.S. Government agency and the Government contract number are:

Respectfully submitted,

SIGNATURE [signature] Date 6/24/03

TYPED or PRINTED NAME AARON WAXLER REGISTRATON NO. 48,027

[ ] Additional inventors are being named on separately numbered sheets attached hereto

CERTIFICATE OF EXPRESS MAILING

Express Mail Mailing Label No, EV 312 069 896 US
Date of Deposit June 24, 2003

I hereby certify that this paper and/or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. 1.10 on the date indicated above and is addressed to the Commissioner for Patents, Alexandria VA. 22313-*1450

Burnett James [signature: Burnett James]
Typed Name **Signature**

S:\WX\PHUS\US030190-DPROV.doc

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of
ALEXEI MAZNEV
Serial No.:
Filed: CONCURRENTLY

Atty. Docket
US030190
Group Art Unit No.:

Title: OPTOACOUSTIC METHOD FORD MEASURING SUDRFACE PROFILE ON STRUCTURES CHARCTERIZED BY SUB-MICRON LATERAL FEATURE SIZE

Commissioner for Patents
Alexandria, VA 22313-1450

AUTHORIZATION PURSUANT TO 37 CFR э1.136(a)(3)
AND TO CHARGE DEPOSIT ACCOUNT

Sir:

The Commissioner is hereby requested and authorized to treat any concurrent or future reply in this application requiring a petition for extension of time for its timely submission, as incorporating a petition for extension of time for the appropriate length of time.

Please charge any additional fees which may now or in the future be required in this application, including extension of time fees, but excluding the issue fee unless explicitly requested to do so, and credit any overpayment, to Deposit Account No. 14-1270.

Respectfully submitted,

By
Aaron Waxler, Reg. 48,027
Patent Agent
(914) 333-9608

S:\WX\PHUS\US030190-DPROV.doc

RETURN COPY OF THE ID ABSTRACT TO:
FOR ADMIN USE ONLY

SUB 27
ID 703621
PS
DSC ~~A65~~ 816
DIV WAXL

EXPORT CONTROL NUMBER (ECCN) NLREAR99

ECO INITIALS 8m 20Sept 2002

FOR CIP USE ONLY

PHILIPS ELECTRONICS NORTH AMERICA CORPORATION

DISCLOSURE OF INVENTION

THIS DESCRIPTION SHOULD BE SUPPLEMENTED BY ATTACHING COPIES OF RELEVANT DOCUMENTS, SUCH AS PUBLISHED ARTICLES OR PATENTS, PRODUCT BROCHURES, ENGINEERING NOTEBOOK PAGES AND DRAWINGS.

DESCRIPTIVE TITLE OF THE INVENTION: Optoacoustic method for measuring surface profile on structures characterized by sub-micron lateral feature size

INVENTOR #1: Alexei Maznev — Sr. Scientist — Philips Analytical, Supply Center Boston
Name (Print) **Job Title** **Division / Location**

Alex.maznev@philips.com — Michael Gostein
E-Mail address **Manager's Name**

6 Saturn Rd., Marblehead MA 01945 — Russian Federation
Home Address **Country of Citizenship**

INVENTOR #2:
Name (Print) **Job Title** **Division / Location**

E-Mail address **Manager's Name**

Home Address **Country of Citizenship**

INVENTOR #3:
Name (Print) **Job Title** **Division / Location**

E-Mail address **Manager's Name**

Home Address **Country of Citizenship**

2002 SEP 17 AM 11:23

D:\MAZNEV\PATENTS\ETCH DEPTH\DISCLOSURE OF INVENTION - ETGFBDEPTH.DOC
Revision June 11, 2001

1. PRIMARY CONTACT

Who should CIP contact for further technical information about the invention and information about its planned use or public disclosure?

Inventor Name: Alexei Maznev

2. PRESENT STAGE OF THE INVENTION

X Idea ☐ Research ☐ Development ☐ Manufacture

3. GOVERNMENT CONTRACT INVENTION

Was the invention made under a government contract? ☐ Yes X No

4. **PLEASE PROVIDE A TWO OR THREE SENTENCE SUMMARY OF YOUR INVENTION and include and underline KEY WORDS which might be useful in searching for relevant patents or publications:**

Photoacoustic transient grating technique also known as ISTS (Impulsive Stimulated Thermal Scattering) is applied to measuring profile of periodic structures with sub-micron feature size such as arrays of etched trenches. The measurement is based on the dependence of the surface acoustic wave velocity on the depth of the profile.

5. PRESENT STATE OF THE ART

Briefly describe the closest already-known technology that relates to the invention. This would include, for example, already existing products, methods or compositions which are known to you personally or through descriptions in publications.

1. ISTS technique implemented in Philips Analytical's Impulse/Emerald instruments is primarily used for film thickness measurement. It would be straightforward to use this technique to measure the etch depth of a film on a substrate if the size of the etched area is of the order of or larger than the probe laser spot i.e. typically ≥30 μm, in which case such measurement will be equivalent to measuring the film thickness inside and outside the etched area.

2. Scanning atomic force microscopy (AFM) is used to measure profile of sub-micron structures.
3. Scatterometry (measurement of the angular distribution of light scattered by the structure) is used to measure the surface profile of sub-micron structures. Unlike AFM, this is an indirect method based on the mathematical modeling of light scattering, and the feature size should be larger than at least a half of the optical wavelength.

D:\MAZNEV\PATENTS\ETCH DEPTH\DISCLOSURE OF INVENTION - ETCHDEPTH.DOC
Revision June 11, 2001

4. An effect of periodic surface relief on the velocity of SAWs measured by the ISTS technique has been previously observed (see L. Dhar and J.A. Rogers, Appl. Phys. Lett. 77, 1402 (2000)). However, it has not been proposed that the method could be used to measure the etch profile depth.

(ADD LINES AS NECESSARY, IF COMPLETING ON COMPUTER, OR ATTACH ADDITIONAL PAGES)

6. ADVANCEMENT IN STATE OF THE ART

Briefly describe the unique advancement achieved by the invention. This may be done, for example, by describing a problem with the prior art that is solved or specific objects that are achieved by the invention.

1. Unlike AFM and scatterometry, the proposed method does not have limitations related to high aspect ratio or small feature size of the structure
2. Compared to AFM, the method has an advantage of being an all-optical technique providing faster measurements and more suited for in-line process control. The profile depth is obtained in a single measurement vs. a linear scan needed in a measurement by AFM
3. Compared to scatterometry, the method has an advantage of simple and straightforward data analysis. The only measured parameter is the SAW frequency. Typically, the smaller the frequency, the larger is the profile depth.
4. The invention extends the range of applications of Impulse/Emerald film thickness measuring instruments.

ADD LINES AS NECESSARY, IF COMPLETING ON COMPUTER, OR ATTACH ADDITIONAL PAGES)

7. WHAT IS THE BEST WAY YOU KNOW OF TO IMPLEMENT THE INVENTION?

Briefly describe the invention and how it achieves the advancement described in paragraph 6

Attached on additional pages

(ADD LINES AS NECESSARY, IF COMPLETING ON COMPUTER, OR ATTACH ADDITIONAL PAGES)

*********PLEASE NOTE: IF WE DECIDE TO FILE AN APPLICATION ON THIS INVENTION, THE ATTORNEY WRITING THE APPLICATION WILL NEED THIS INFORMATION FROM YOU IN AS MUCH DETAIL AS POSSIBLE IN ORDER TO COMPLETE THE APPLICATION.**

8. DISCLOSURE OUTSIDE OF PHILIPS

If the invention has been or will be disclosed publicly or to anyone other than a Philips' employee, describe to whom (person / company), date and where.

The invention has not been disclosed outside of Philips

9. PUBLICATION

Has a description of the invention been published or submitted for publication? ☐ Yes X No

If "yes", please list each occurrence:

Date	Publication/Submission

10. **PLEASE INDICATE THE PRODUCT OR SERVICE IN WHICH YOUR INVENTION MOST LIKELY WILL BE USED:**

Philips Analytical's optoacoustic product line (Impulse/Emerald)

INVENTOR #1: A Mey 09/13/02
Signature Date

INVENTOR #2:
Signature Date

INVENTOR #3:
Signature Date

D:\MAZNEV\PATENTS\ETCH DEPTH\DISCLOSURE OF INVENTION - ETCHDEPTH.DOC
Revision June 11, 2001

M asuring d pth of sub-micron tr nch arrays by ISTS

I. Outline of the m thod.

In the prior art, laser-induced transient grating technique, or ISTS, has been used to measure film thickness via measuring the phase velocity of Surface Acoustic Waves (SAWs) propagating in the filmstack. If the film is patterned e.g. by etching, it would be straightforward to use ISTS for measuring the etch depth if the size of the etched area is large compared to the SAW wavelength (typically 2-10 μm). In this case measuring the etch depth means simply measuring a change in the film thickness (see Fig.1). Note that it can only be done for a thin film on a substrate made of different material so that the SAW velocity be dependent on the film thickness. The prior art method will not work at all if one needs to measure surface profile of a bulk sample, e.g. a silicon wafer.

In the state-of-the-art integrated circuit manufacturing, typical pattern feature size is of the order of 0.1 μm i.e. much less than the SAW wavelength in an ISTS measurement. Although larger features may be also present within a die, it is the smallest features that are most likely to be misprocessed during lithography and etching, and, consequently, require process control metrology. According to the current invention, ISTS can be used to measure depth profile of a periodic structure with near- or sub-micron feature, e.g. a periodic array of trenches etched either in a thin film or in a silicon substrate (see Fig.1). The measurement is based on the fact that the SAW phase velocity is affected by periodic surface relief. This effect have been reported previously [1-2], but the application of the effect to measuring surface profile has not been proposed. Also, no studies have been done for high-aspect-ratio sub-micron structures which are of the most interest for practical applications.

According to the invented method, the measurement process is similar to an ISTS measurement known from the prior art, except of the fact that the excitation and detection of SAWs is performed on a patterned sample with surface profile characterized by a period of the order or less than 1 μm. The measurement yields the SAW frequency at a defined wavelength, from which the SAW phase velocity is calculated. The data are analyzed with the help of an analytical or empirical model to determine a parameter of the profile, typically the trench depth or width / space ratio.

II. Theor tical mod l for high aspect ratio tr nch arrays.

Previous theoretical work [1] was done for shallow surface relief permitting the use of perturbative approaches. Accurate analysis of high aspect ratio structures would require finite element calculations. Here, we are considering an approximate model in order to obtain at least an estimate of the effect of high aspect ratio trench array on SAW propagation. The model applies to periodic arrays of trenches such as those shown in Fig. 1 , with the period smaller than the trench depth. The model assumes that if the period of the structure is small with respect to both SAW wavelength and thickness of the structure, the structure can be treated as a homogeneous material with effective elastic properties. In Ref. [3], it was shown how to calculate the effective elastic properties of a layered structure from the properties of constituent materials. The layered structure is effectively described as a transversely isotropic medium with the symmetry axis perpendicular to the layers, which is described by 5 independent effective elastic constants. The same method can be applied to a trench array if vacuum is treated as one of the constituent materials of the structure. From the equations of Ref.[3], we obtain the following equations expressing effective density ρ^* and elastic constants C_{ij}^* of the trench array through the density ρ and elastic constants C_{ij} of the material:

$$\begin{aligned} \rho^* &= h\rho \\ C_{11}^* &= h\left(C_{11} - \frac{C_{12}^2}{C_{11}}\right) \\ C_{66}^* &= hC_{44} \\ C_{13}^* &= C_{33}^* = C_{44}^* = 0 \end{aligned} \qquad (1)$$

where h is the ratio of the space between the trenches to the period of the structure. It can be expressed trough the trench width/space ratio as h=1/(1+w/s). The notations in Eq.(1) assume that the z-axis is perpendicular to the trenches.

For SAW propagation along the x-axis i.e. along the trenches, a transversely isotropic medium with the z symmetry axis is equivalent to an isotropic medium and the only elastics constants that matter are C^*_{11} and C^*_{66}. Therefore, a standard computer code for SAW propagation in a film/substrate structure can be used to analyze this case. Analysis of the propagation across the trenches is more complicated because some acoustic velocities are equal to zero and the standard code cannot handle the situation. For this case, I did a simplified analysis, modeling a trench array as a mass loading lacking any elastic strength.

Fig. 2 presents the calculated dependence of the SAW velocity on the trench depth for trench arrays with width/space ratios 1:1 and 1:3 fabricated in Si and in a 1 μm-thick thermal oxide film on

Si. The calculations were done for SAW wavelength 6 μm. The calculations show that there is a significant dependence of the SAW velocity on both the trench depth and width/space ratio, particularly for SAW propagation across the trenches. In order to estimate the repeatability of the trench depth measurements, let us assume that the repeatability of the SAW velocity measurements is ~0.5 m/s (which corresponds to the frequency measurement repeatability of 0.1 MHz). For a trench depth of 5000 Å and SAW propagation perpendicular to the trenches, the results presented in Fig.(2) yield a repeatability estimate of ~7 Å (or 0.14%) for 1:1 width/space ratio trenches in Si and ~20Å (or 0.4%) for trenches in the oxide film.

It should be noted that variations in trench depth and width have different effects on SAW velocity parallel and perpendicular to the trenches. An increase in the trench width increases the parallel velocity but decreases the perpendicular velocity while an increase in the trench width/space ratio increases the SAW velocity in both directions. This fact indicates that the measurements with SAW propagation along and across the trenches could be combined in order to determine both trench depth and width/space ratio.

III Experiment

Experiment was done at an acoustic wavelength of 6 μm on an array of 1 μm-wide trenches with 1:1 width/space ratio etched in an 8000 Å-thick layer of CVD oxide on Si, and covered with ~250 Å of PVD Ta and ~1000 Å of PVD Cu (see Fig.3). Note that this structure does not correspond to the theoretical model considered above because of the presence of the metal coating and also because the aspect ratio of the trenches is not high enough and the structure period is not too small compared to the wavelength. Therefore, the experiment was performed not in order to quantitatively verify the theoretical model but rather in order to demonstrate that a structure with deep trenches yields a good signal for SAW propagation direction both parallel and perpendicular to the trenches and also that there is a significant effect of the surface profile on the SAW velocity.

Fig. 4 presents the signal waveforms obtained in the unpatterned area of the sample and on the trench array with SAW propagation parallel and perpendicular to the trenches. It can be seen from the waveforms, that for the perpendicular propagation, the effect of the surface relief on the signal is particularly strong and that it causes a significant decrease in the SAW velocity. Table 1 lists the values of the SAW velocity obtained from the measured waveforms. The fact that the presence of the trenches increases the SAW velocity for the parallel propagation and decreases it for the perpendicular propagation qualitatively agrees with the theoretical model.

Reference

1. L. Giovannini et al., Phys. Rev. Lett. 69, 1572 (1992)
2. L. Dhar and J.A. Rogers, Appl. Phys. Lett, 77, 1402 (2000).
3. M. Gostein and A.A. Maznev, invention disclosure #703048

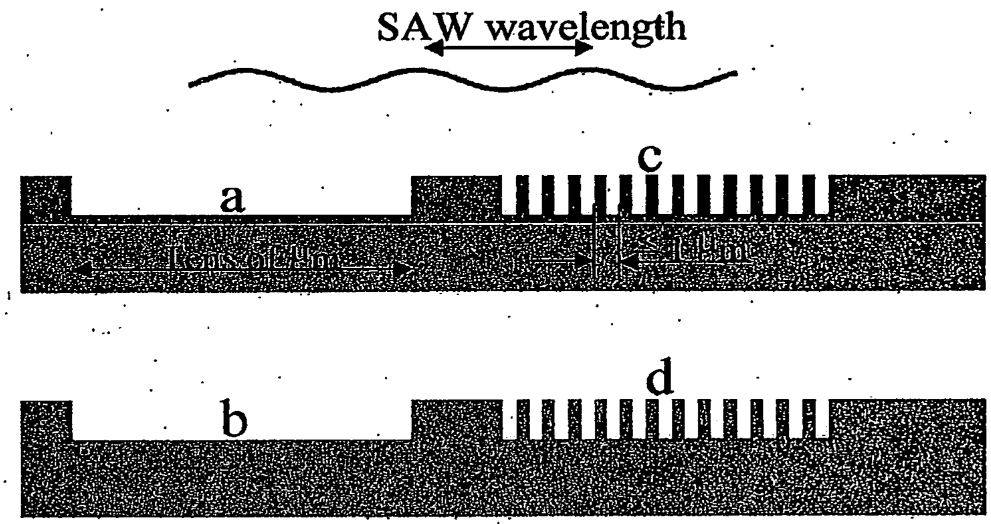

Fig. 1 Patterned film on a Si substrate (top) and patterned Si substrate (bottom).

The method proposed ion the invention measures the trench depth on structures (c) and (d). Structure (a) can be measured by a prior art method, structure (b) cannot be measured by ISTS as of now.

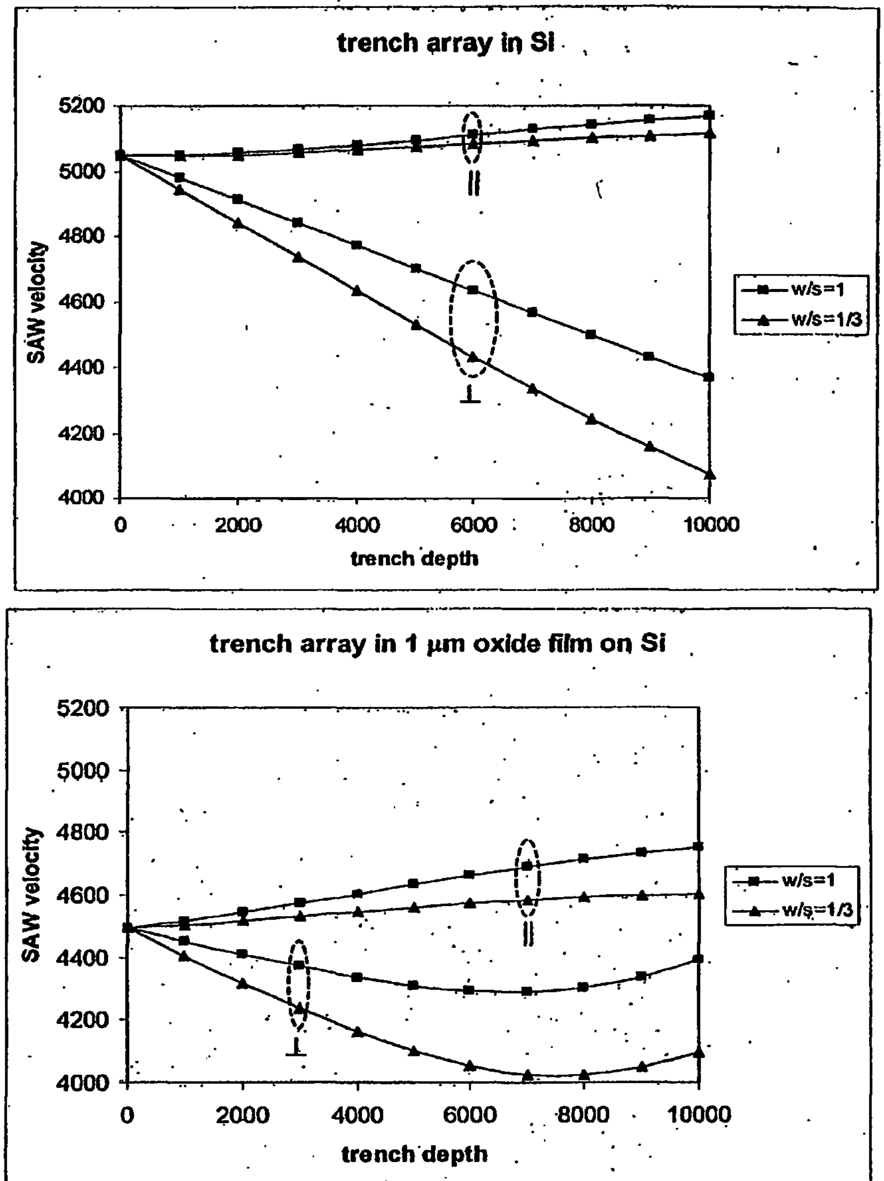

Fig.2 Calculated dependence of the SAW velocity on the trench depth for trench arrays with width/space ratios1:1 and 1:3 fabricated in Si (top) and 1 mm-thick thermal oxide film on a Si substrate (bottom) for SAW propagation parallel (||) and perpendicular (⊥) to the trenches.

D:\MAZNEV\PATENTS\ETCH DEPTH\DISCLOSURE OF INVENTION - ETCH DEPTH.DOC
Revision June 11, 2001

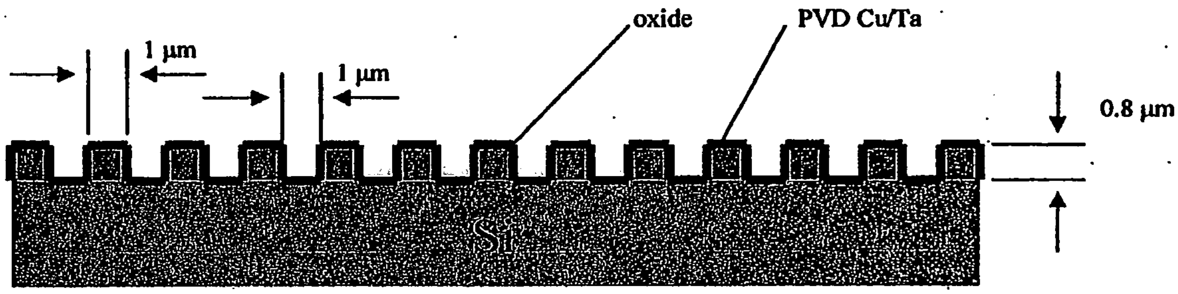

Fig. 3 Structure measured in the experiment

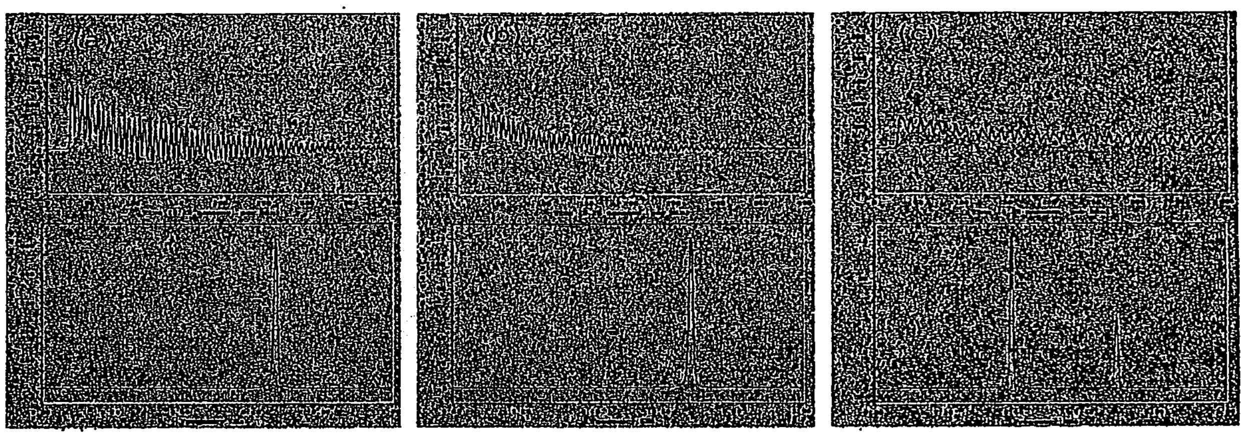

Fig. 4 Signal waveforms obtained at acoustic wavelength 6 µm on a sample with filmstack 1000 Å Cu / 250 Å Ta / 8000 Å oxide / Si. (a) unpatterned area of the sample, (b) 1 mm width x1 mm space trench array, SAW propagation parallel to the trenches; (c) SAW propagation perpendicular to the trenches.

M asurement location	SAW v locity (m/s)
Unpatterned area	3930
Trench array, parallel	4016
Trench array, perp ndicular	2299

Table 1. SAW velocities determined from the waveforms presented in Fig. 4

ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.